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A redesign of the Navy's enlisted personnel distribution process

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THESIS

A REDESIGN OF THE NAVY'S ENLISTED PERSONNEL DISTRIBUTION PROCESS

by

Gerard Keng Swee Koh

March 2002

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Past studies show that significant positive results can be reaped if a 2-sided matching algorithm is used in the Navy enlisted distribution process. This includes ensuring that commands get the quality of sailors that they demand while satisfying sailors' preferences of their next billet, and thereby improving their motivation and propensity to reenlist. Past studies have also examined the current process in the Navy and detailed its shortcomings. Other research has also detailed the possible uses of optimization technology, smart agent technology, employee-to-job matching algorithms, incentive driven assignments and other technologies to improve on employee-job assignments in large hierarchical internal labor markets, like those found in the military. It is also noted that there are constraints within the military that can pose challenges to the direct application of these technologies to improve the process. These constraints can be structural, behavioral, political, and cultural. To improve the current process, both the available technologies and constraints need to be reexamined holistically and the technologies and current personnel policies modified to meet these needs. This study looks at these issues and proposes an alternative design of the Navy enlisted distribution process that will yield quantum gains for the Navy and its sailors. It details the key operational and user specifications required of a prototype Navy enlisted distribution decision support system.

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A REDESIGN OF THE NAVY'S ENLISTED PERSONNEL DISTRIBUTION PROCESS

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I. INTRODUCTION AND OVERVIEW

A. OVERVIEW AND BACKGROUND

1. Overview

This thesis proposes a redesign of the U.S. Navy’s enlisted distribution process. It begins by examining the technologies available for redesigning the Navy personnel enlisted distribution process. It then analyzes the problems with the current process and seeks ways to implement technology and process innovations to improve the current process. It integrates past and ongoing studies in this area into a holistic study and proposes an innovative and practical redesign of the process. It studies the integration of optimization technology, two-sided matching algorithms and smart agent technologies into the process. It considers Navy policies and operating constraints that may require adjustments of these available technologies and processes to be applicable to the requirements. As an eventual output, the study specifies the key operational parameters for a prototype decision support system to be considered.

2. Background

The U.S. Navy manpower, personnel, and training (MPT) process cycle ends in the distribution process. After the earlier stages of defining requirements, programming these requirements, and planning, distribution is the final process of putting sailors and officers into billets. In order to fulfill the Navy’s needs, distribution is the execution phase of filling ‘spaces’ with ‘faces.’ Arguably, this is the most important phase of the process as it identifies individual billets that are required to be manned and staffs them with the best sailors and officers identified to fulfill the job requirements. All the other earlier detailed processes in the MPT system will come to naught if the distribution process is not carried out effectively and efficiently. To this effect, an agenda to improve the distribution process was set by the Chief of Naval Personnel (CNP).

CNP 's Agenda and Ongoing Studies. In the 1998 document "Sailor 21: A Research Vision to Attract, Retain and Utilize the 21st Century Sailor" (NPRST), CNP's vision provides a clear mandate for using technology to alleviate the challenges of manpower and personnel management in the Navy in the 21st century. In the area of distribution, it is envisioned that sophisticated decision support systems will be used to augment the decision making process of sailors when they choose their next billets and detailers as they match sailors to billets. Intelligent software agents can assist sailors to make informed choices as they scour the Navy market place for jobs for which they are suited. Optimization and matching models in new decision support systems can assist detailers in balancing the Navy's needs and the Sailors' needs. The agenda spelt out in the document provides the impetus for more research and to generate alternative designs in the area of enlisted distribution.

In 1999, the Recruiting, Retention, Training and Assignment Working Group, established by CNP, developed concepts for the future distribution process that would leverage on web based intelligent agents and other decision support systems to represent the full interests of the Navy and sailors. These concepts also included better defined career paths, vacancy driven distribution based on deployment cycles, customer focused detailing and placement activities, and an incentive system that rewards sailors who take on the more arduous assignments. The new systems are envisioned to ride on the Navy/Marine Corps Intranet via a web-based "marketplace" environment. The Naval Postgraduate School (NPS) together with the Navy Personnel Research, Studies, and Technology (NPRST) are currently engaged in a series of studies to specify the requirements of such a system.

Benefits of an Improved Distribution Process. The current distribution process is complex, highly dynamic, and time sensitive. It not only involves getting the right person into the right job, but also impacts on the motivation of sailors and officers who seek to get the job they desire, which in turn impacts performance and retention. Ultimately the manning levels and operational readiness of the Navy is at stake. Therefore, unlike the other phases of the MPT system, the distribution process must not only consider the

needs of the commands but also the needs of the personnel. This ‘dual requirement’ subjects the process to large dynamic variability and subjectivity. Any redesign efforts for the distribution process must consider these two sides of the same coin.

A distribution process that is perceived as fair and objective by the sailors, while also filling the requirements of the Navy, has three main benefits : 1) Improved sailor retention rates, 2) Better motivated sailors and 3) Ensuring the Navy’s requirements are met.

- **Retention**. Retention will be improved if sailors perceive that the assignment process is fair, objective and that their needs are taken more into account. Currently the process is biased towards filling the requirements of the commands and the needs of the sailors are subordinated to the command’s needs. The culture of the Navy encourages the sailors to put the organization above one’s self. However, given the many pulls from the private sector and family demands, the sailors’ career needs will also have to be taken care of if the Navy is to successfully retain them. In a ‘customer’ satisfaction survey conducted by the Navy Personnel Command, half of the sailors who reported that they were dissatisfied with the detailing process reported that they are likely to leave the service (ORC Marco, 2000).

- **Motivation**. Seen from the point of intrinsic motivation, sailors are more likely to be intrinsically motivated by their jobs if they have a choice in the jobs they would like to perform. Thomas’s framework predicts that intrinsic motivation makes workers feel energized by the task they perform (Thomas, 2000). The feeling is one of excitement and enjoyment coupled with a want to learn more to do their jobs better. In contrast, a lack of empowerment makes workers feel lethargy and drudgery for their jobs. When workers self manage, they feel a sense of empowerment. The process of self-management is described in Figure 1:

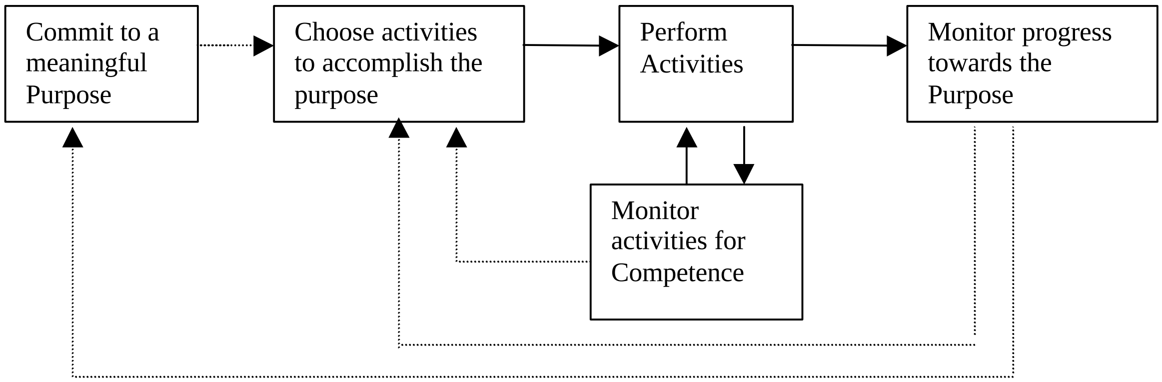

Figure 1 – The Self Management Process

The process begins with workers committing to a Purpose and taking a personal responsibility of making it happen. Next, they choose the activities to achieve the purpose. They then perform these activities and monitor them for their progress towards achieving of the Purpose and for how well they satisfy the standards set as a measure of their competence. They then use their observations to review the purpose they committed to, the activities chosen to accomplish them and the conduct of these activities. This self management process will generate in them feelings of Choice (the freedom to decide and act in ways they judge as appropriate), Meaningfulness (that their tasks are of significance to the larger scheme of things), Competence (that they are good at what they do) and Progress (that what they set out to do is on the way to accomplishment). These feelings in turn lead to feelings of empowerment and result in higher motivation. At the heart of the matter is the issue of Choice. Although the concept of military service implies “duty over self,” this does not preclude the idea that sailors still can and must be given choices when they are in the Navy. Sailors must freely believe in their hearts and minds that they have a meaningful part to play. They must have choices about how to fulfil that purpose given the organization’s constraints. Thus it is seen that giving the sailor a sense of choice in the jobs they are to perform is key to motivation.

- **Meeting the Navy’s Needs**. The billets in the Navy need to be filled by the

right person with the right training, in the right billet, and at the right time; also known as the “R4” of the MPT process. A redesigned process will better ensure that this dimension of distribution will be optimized to meet the Navy’s manpower requirements.

This thesis seeks to redesign the enlisted distribution process while balancing the dual needs of Commands and Sailors requirements in balance.

Integrating Current Studies within Navy Constraints. Past studies have examined using of two-sided matching algorithms in the Navy enlisted detailing process. They report that significant positive results can be reaped if two-sided matching is used in the assignment process. This includes ensuring that commands get the quality of sailors that they demand while satisfying sailors’ preferences for their next billet and thereby improving sailors’ motivation and propensity to reenlist. These simulation studies (Ng and Soh) and experiments (Tan and Yeong) also show that, on average, a two sided matching algorithm gives a higher total utility to both commands and sailors than if the matching was done manually by detailers.

Past studies have also examined the current process in the Navy and the Army and detailed their shortcomings. Research conducted outside of the military has also detailed the possible uses of optimization technology, smart agent technology, employee-to-job matching algorithms, bidding systems, incentive driven assignments and other technologies to improve on employee-job assignments in large hierarchical internal labor markets, like those found in the military. It is clear from these studies that there are significant benefits to be gained if these technologies can be leveraged to significantly improve the enlisted assignment process

It is also noted that there are constraints within the military that can challenge the direct application of these technologies to improve the process. These constraints can be structural (organization and policy), behavioral, and cultural. An example of a structural constraint is the policy to reassign married couples in the Navy together at the same time

and to the same geographic location (tied movers). This will pose a special problem for two-sided matching algorithms that do not account for tied movers. A behavioral constraint to using auction technology is the propensity of players (commands and sailors) to game the system. An example of a cultural constraint is the practice for commanders to provide career counseling to their sailors under them via command career counselors. This promotes a paternalistic and 'family' culture in commands that show the commands' and Navy's concern for the sailors' career and welfare. However, this culture may be eroded if career counselors are completely replaced by smart agent systems and expert systems that provide online advice to sailors. There may still have to be a human-to-human interface for career counseling tasks.

Thus, although the technology is available, it must be modified to fit the structural, behavioral, and cultural constraints before it can considerably improve the distribution process. To improve the current process, both the available technologies and constraints need to be reexamined holistically. Technology can then be adjusted, and constraints can be altered or removed within the scope of a process redesign.

B. PURPOSE

NPRST aims to develop a prototype of a decision support system(s) and to test the system(s) on a selected community of Navy enlisted servicemen. Before the prototype can be built, a redesigned assignment process must be specified – one that leverages on technology to provide dramatic improvements in the outcomes. Importantly, the output requirements, the data requirements, models, algorithms and decision variables required in the prototype must also be specified before it can be built.

Previous studies in improving the distribution process have just looked at using technology to augment the current processes. A holistic innovative process redesign approach is taken in this thesis rather than merely an introduction of technology to augment the current processes. It is strongly believed that using technology to 'pave the cow paths' is not the optimal method of improving the effectiveness and efficiency of the

distribution process. In fact it may lead to resistance to the application of such technology, inability to integrate and rationalize processes with the technology used, and eventually to the failure of the system. This study aims to redesign the process while using technology levers to perform tasks that previously were not available. The end result will be a rationalized process that will achieve quantum improvements in efficiency (requiring less resources) and effectiveness (better sailor to billet matches and higher command and sailor satisfaction) over the current process.

This study looks at these issues and proposes an alternative design of the Navy enlisted distribution process that will yield quantum gains for the Navy and its sailors. It integrates the varied studies done so far in the area of improving the military's enlisted assignment process together with new knowledge in cutting edge decision support systems and expert systems, and analyzes the constraints inherent in the Navy's policies and objectives. It also details the key parameters required for a prototype Navy enlisted distribution Decision Support System (DSS) design. It is hoped that the design specifications detailed in this paper will lead to a complete and detailed study of the proposed design, ultimately leading to a prototype being built.

C. RESEARCH QUESTIONS

1. Primary Research Questions

a. What is a practical and innovative redesign of the distribution process, leveraging on technology that can dramatically improve the effectiveness and efficiency of the distribution process?

b. What are the key operational specifications required of a prototype decision support system?

2. Secondary Research Questions

To arrive at the results required in the primary research questions the following

secondary research questions are addressed:

a. What are the advantages and shortfalls of the current Navy enlisted assignment process?

b. What are the measures of success for the process and what are the key success factors?

c. What are the technologies available to improve the current process and in what areas can they contribute to the process's efficiency and effectiveness?

d. What Navy enlisted policies need to be changed and constraints overcome? What policies are sacrosanct?

e. How can the available technology be integrated within sacrosanct Navy policies and constraints?

f. What are the key elements of a redesign of the current process?

g. What are the specifications and components required in the decision support models?

D. SCOPE, LIMITATIONS, AND METHODOLOGY

1. Scope

This thesis covers the following areas:

a. A summary of the current Navy enlisted assignment process including a description of the current process and its advantages and shortcomings.

b. A review of enabling technologies and studies that have been conducted. This aims to identify technological and process change levers to improve the process.

c. An identification of Critical Success Factors (CSFs) and constraints. This includes defining key success factors and identifying

constraints of the Navy that hinder the direct use of available technology. Sacrosanct constraints and those that are flexible will be identified.

d. A process redesign where design solutions are proposed to overcome sacrosanct constraints.

e. Finally, a proposed design of an improved enlisted distribution process and specification of key parameters for a decision support system to support the new process.

2. Limitations

Notably, this study does not cover the Navy officer distribution process. It does not detail the decision supports systems' development process and system development life cycle but merely details the output requirements and possible technologies that can produce these outputs. The Navy enlisted distribution process consists of 3 sub processes: allocation, placement and assignment (i.e. detailing). The main focus of this thesis will be on the placement and assignment sub processes, although the allocation sub process will be considered in the process redesigns.

3. Methodology

The methodology used in this thesis research consists of the following steps:

a. Conduct of a literature review of thesis projects, journal articles, presentation and briefing notes, books, magazines and newspaper articles, CD-ROM systems, and other library information resources.

b. Review current Navy manpower planning policies particularly in the area of assignments.

c. Analyze opportunities afforded by the available technology using Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis.

d. Analyze Navy constraints that hinder the direct use of available technology using the 4 Management frames – Structural, Human

Resource, Political, and Symbolic frames.

e. Interview and conduct discussions with key personnel in the Navy assignment community in NPRST, N1, and other civilian research institutions.

f. Propose a redesign of the Assignment process including specifications of key design parameters.

E. BENEFITS

NPRST is currently studying ways to improve the current distribution process and to build a prototype to test the system on a community of enlisted sailors. This study provides insight into the design of a prototype system to better match sailors to billets. It also integrates the technology with a redesigned process with processes and policy guidelines to radically improve the effectiveness and efficiency of current assignment. It serves as a platform where a more complete and detailed design specifications can be made and a prototype built and tested within the context of an appropriate redesigned enlisted distribution process.

II. LITERATURE REVIEW AND SWOT ANALYSIS

A. SUMMARY OF THE CURRENT NAVY ENLISTED DISTRIBUTION PROCESS

1. Description of the Current Process

This section summarizes the enlisted distribution process, focusing on the players and their relationships in the system, the handoffs, and the technologies used. This leads to an analysis of the shortcomings of the process and how process redesign and technology can help improve it. This discussion is partly based on “Alternative Redesigns Of The Navy Enlisted Distribution process” (Butler, Koh and Molina). A detailed description of the Navy’s current Enlisted personnel distribution process can be found in Melissa Short’s “Analysis of the Current Navy Enlisted Detailing Process” (Short, 2001).

a. The Distribution Triad

The distribution process consists of three sub-processes, known as the Distribution Triad. They are: allocation, placement, and detailing. A summary of the distribution process, is as shown in Figure 2.

Allocation apportions the projected distributable inventory of enlisted personnel to the various Manning Control Authorities (MCA) to fill their projected billet requirements.[1] Placement represents the command’s requirements to the job-sailor matching process. Detailing represents the sailors’ needs and actually matches jobs to the right sailor.

[1] The four Manning Control Authorities are: Pacific Fleet (PACFLT), Atlantic Fleet (LANTFLT), Bureau of Personnel (BUPERS) and Reserve (RESERVE). Together they cover the Navy’s entire scope of operations and are responsible for the manning of the billets under their charge.

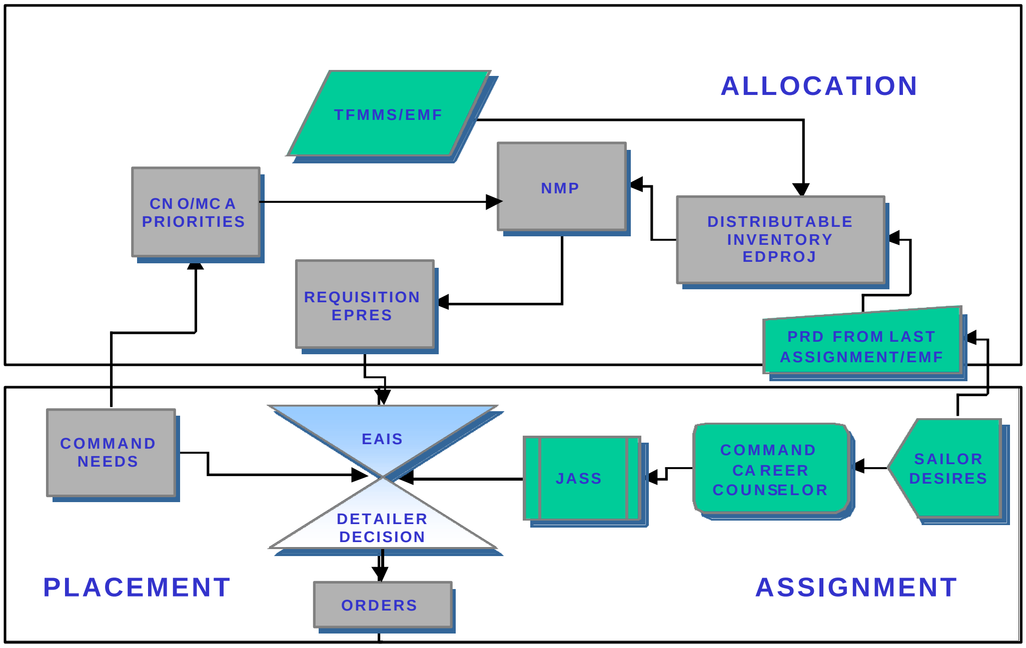

Figure 2 – The Navy Enlisted Distribution Process

These three sub-processes work in concert to fulfill four important objectives of the distribution process. Firstly, that the commands get their fair share of sailors available for distribution and thus maintain a manning level required to ensure operational readiness. Secondly, that the command's different requirements for sailor type and the time that each sailor is required for each billet are considered in the process and fulfilled. Thirdly, that sailors' needs and preferences, and overall organizational policy objectives are incorporated in the process. Fourthly, through a matching process, that all these requirements are fulfilled and needed compromises take into account the overall organizational goals, commands' needs, and sailors' needs.

b. Allocation

The objective of allocation is to distribute the available inventory of sailors to the commands in order to fill the manning objectives set by the Chief of Naval Operations (CNO). The end product of the allocation phase is the Navy Manning Plan (NMP), which is a document that shows the prioritized allocation of distributable inventory to the various commands. This document then guides the processes in the placement and detailing phase as it specifies who gets how many of what type of sailor (Rank, Ratings, MOS, NEC). The allocation process consists of three steps: 1)

establishing the distributable inventory; 2) establishing the billets' requirements; and 3) allocating the projected inventory to the projected billet requirements.

Step 1 : Establishing the Distributable Inventory. This step essentially determines the supply of enlisted personnel. To establish the distributable inventory, the Naval Personnel Center (NPC) in Millington, Tennessee first identifies the sailors who are due to be rotated nine months out. From this stock of sailors, it then excludes those who are not assignable, including those who are transients, patients, prisoners, and holdees (TPPH), those projected to be on training (awaiting instruction), and those whose End of Obligated Service (EOS) is less than nine months out (i.e. projected to leave the Navy within the next nine months). The net inventory of sailors left is the distributable inventory, i.e. the sailors that can be reassigned to another billet nine months out.

Data is retrieved from two databases, the Enlisted Master File (EMF) and the Total Force Manpower Management System (TFMMS). The EMF provides data on enlisted personnel (Rating, NEC, date of last assignment, etc.), while TFMMS provides data on billets. Projections of which sailor can be rotated nine months out is done by the Enlisted Data Projection System (EDPROJ), which combines data from the EMF and TFMMS with policy guidelines to generate a projection of sailors who can rotate to new jobs. This list of distributable sailors is then passed the Enlisted Placement Management Center (EPMAC) together with the billet requirements generated in step two. The hand-over is done electronically via the Navy's computer network.

Step 2 : Establishing The Billet Requirements. Also prepared by NPC, this step involves identifying the projected 'job vacancies' nine months out, i.e. the demand. It follows from step one above that when sailors are projected to rotate nine months out, their current billet will in turn be vacant in nine months when they rotate. Also, due to sailor attrition (unplanned losses) and pending reenlistments, there will be additional billets that need manpower replacement. This data is generated using the systems in step one (EMF, TFMMS, and EDPROJ). EDPROJ uses historical attrition rates, reenlistment (retention) rates, and mathematical models to project the potential losses and the

additional billets that need replacement. The combined requirements of each and every job that needs a sailor to be staffed nine months out is then sent electronically to EPMAC, together with the distributable inventory data.

In short, step one and two identify, by name and description, each and every sailor and billet that need to be matched nine months out. It must be noted that this is largely a projection and is subject to some dynamic changes in the forthcoming nine months. (e.g. reenlistment rates may change, attrition rates may vary, billets may be deleted or added).

<u>Step 3 :Allocating The Distributable Inventory</u>. EPMAC uses the data from NPC to produce the Navy Manning Plan (NMP). The NMP is the prioritized distribution of distributable inventory to the various commands. With projected 'supply' and 'demand' data generated in steps one and two, EPMAC can then distribute the inventory based on policy guidelines and manning targets. The goal of EPMAC is to ensure that the commands get sufficient numbers of sailors to maintain a targeted manning level.

This allocation follows a prioritization process laid out in CNO directives and with input from the MCAs. EPMAC allocates sailors in every rating to ensure each class of jobs (e.g. Corpsmen, Electronic Technician) is manned at a targeted manning level. Jobs that require a higher manning level (e.g. 100% for nuclear submarines and ships that are to deploy) get a higher priority to be filled first. The commands that do not have a target manning level (especially shore installations) get the number of sailors remaning after the higher priority jobs are filled. They will get a number of sailors that ensures they have a 'fair' manning level compared to the other non-priority commands. Because of a persistent shortage of sailors, these non-priority billets have to bear a shortfall based on an 'equal misery' policy that spreads the remaining sailors evenly across commands. Note that at this stage, EPMAC does not allocate names, only numbers.

With these guidelines indicating ‘who gets how many,’ the NMP guides the placement and detailing process, which detailers then use to match the correct quantity and quality of sailors to the correct billets to meet the manning targets. The NMP is compiled and electronically transferred into the Enlisted Personnel Requisition System (EPRES) that generates a requisition for personnel through Requisition Posting Module (RPM) in the Enlisted Assignment Information system (EAIS) that is used by Detailers.

c. Placement

Placement is the second leg of the Distribution Triad. Though different, it is accomplished simultaneous to the assignment process. The objective of the placement process is to act as the command advocate, checking that authorized billets are filled with qualified people. This is accomplished by ensuring the four “rights”—1) the right person; 2) with the right training; 3) in the right billet; and 4) at the right time. The Placement Officers advocate the commands’ billet requirements with the Detailers. Placement Officers essentially serve as ‘brokers’ to ensure that the commands they represent get their required quality and quantity of sailors. Placement Officers deal with a multitude of different ratings and MOSs whereas Detailers generally deal with only one particular rating and MOS. Thus, Placement Officers deal with many different Detailers and vice versa.

EPMAC is the principal agent for the enlisted placement function. Other offices within BUPERS handle placement for special assignment categories. Placement is responsible for the timely replacement of unplanned losses. Though manpower intensive, the personal attention paid to handling unplanned losses is successful in maintaining a high level of readiness.

d. Assignment (Detailing)

Assignment or ‘Detailing’ as it is more commonly known, is the third sub-process in the distribution triad. Assignment occurs simultaneously with the second sub-

process placement. Assignment assigns names to the faces that fill the previously allocated spaces. The detailer is the agent in the assignment process. The detailer's goal is to cost effectively match sailors with the necessary skill sets to the prioritized requisitions.

The detailing process begins with its own parallel processes. First, the detailer views the distributable sailor inventory in EAIS nine months before this inventory is to complete their current obligated tour of duty. At the same time, the sailor views the available jobs through the Job Advertising and Selection System (JASS). Sailors can use JASS at their convenience to view upcoming jobs, discuss their options with their Command Career Counselor (CCC), and make an educated and informed request for their next assignment. JASS permits sailors to view upcoming jobs in their pay grade and rating or NEC. View-only JASS is accessible by any sailor or officer in the Navy from any computer terminal with Internet access.

The CCC is an individual with a specific skill set and training that affords them the NEC and sometimes the rating of CCC. Larger commands possess specified billets for a CCC whereas CCC duties are collateral at smaller commands and are performed by an individual who holds the appropriate NEC secondary to that of his/her primary rating.

The CCC uses a combination of training, experience and written manuals as guides to whether the sailor holds the qualifications necessary to obtain their desired job. The CCC considers all the sailors' desires and personal concerns, which include but are not limited to, home ownership, career of their spouse, stability for their children and location, as well as accounting for sailors' career path that affords them the best possibility for advancement. After an agreement has been reached, the CCC accesses a secondary screen in JASS, which is not accessible to sailors, and applies for the job(s) on behalf of the sailor. Using JASS, the CCC helps sailors apply for up to five different jobs, in preference order.

The requisition cycle for detailing is two weeks. Available, allocated jobs are placed into JASS every two weeks. At the end of two weeks, the cycle is officially closed and the detailer then accesses the system to start manually matching jobs with personnel. When requisitions close, the detailers spend approximately four days reviewing constituents' desires and matching the best-qualified person to the available positions. JASS leveled the playing field for all sailors by instituting batch processing versus the old process of first come first served.

Detailers have to juggle a set of requirements and guidelines when matching sailors to billets. Requirements are 'must have' attributes that a sailor must possess before he can be considered for a particular billet. They include the sailor's rate, rating, NEC, skill set viz. billet requirements, gender, PRD, sea-shore rotation cycles and security limitations. If the sailor does not possess the necessary skill set, but meets all other requirements, the detailer then considers school quotas. If an opening exists, the sailor can be sent to school en route to their new assignment, to obtain the necessary skill set for the job. Guidelines are 'should have' attributes that guide the detailer to choose one sailor over another with the 'must have' requirements. They include requisition policies, manning targets, fleet balances, JASS preferences, PCS costs, co-location of married couples, and promotion/career opportunities.

After the detailer has made assignment matches, the detailer accesses the orders writing screen in EAIS to begin the order writing process. For E-6 sailors and above, once the orders are electronically assigned, before the paper copies are written, the electronic orders are reviewed by EPMAC for quality of fit. EPMAC has the authority to veto preliminary assignments between detailers and sailors E-6 and above. This ensures that the detailers' assignment best matches sailors to jobs. EPMAC placement specialists can veto orders that fail to meet fleet readiness manning and balance targets, even if the orders are exactly what the E6 or above sailor requested. Once approved, the sailor receives written orders.

After the sailors are assigned to available positions, the new requisitions

are uploaded from NMP and the detailer releases the new billets into JASS, restarting the two-week cycle. Sailors and billets who are not matched in the previous cycle are rolled over to the next cycle to be considered again.

2. Shortcomings of the Current Process

Commands Do Not Get Their Requirements (Quantity and Quality). Detailers are supposed to maintain the fleet balance by ensuring that enlisted personnel are equitably distributed to all activities among the MCA's by rate, rating, and the NEC in proportion to the Enlisted Master File (EMF) delineated by the NMP. However, because the billets required to be filled often out number the quantity of personnel available to fill the billets, some commands are not assigned enough personnel to meet their requirements. The priority system established by the CNO and the MCAs helps to ensure that higher priority requirements, like joint operations and deploying units, receive their fair share of the requirements. This process leaves other commands without the number of sailors that they need. They are forced to do more with less. Also, the sailors who are left to fill billets, after the priority one, two and three billets are filled, may not be the preferred sailor for the position or vice versa. Some commands may receive a body and have their requirements filled, but the caliber of sailor that is filling the position may be far less than what the command desires.

Non-optimal assignments. Commands may not end up with the best sailor for the job. Detailers have to deal with about 45 sailors and 60 billets per two-week batch. Matches are done manually and have to consider a broad range of variables. This makes it nearly impossible for detailers to optimally match sailors to billets, as they have to rely on rules of thumb to handle the multitude of variables that often have trade-offs with each other. Also, CCCs largely consider the sailors' needs and likely do not fully consider the needs of the fleet (at least not from the macro perspective as CCCs lack that information). Thus, a sailor most suited for one billet from the command's perspective may be advised to apply for another billet. Sailors who apply for the job via JASS may not be the most suitable or desirable by the commands. The detailer can override the preferences of

sailors and assign sailors where they best fit command requirements, regardless of their preferences. However, sailors who are not selected for their preferred job choices (i.e. a non-optimal match from the sailor's perspective) will become disgruntled. This leads to discontent with the process reduces intrinsic motivation and increases the sailor's propensity to leave the Navy

Subject to Human Error (Detailers and CCCs). Currently, there is no single tool to assist the detailers to mentally juggle the plethora of diverse policies, procedures, and information to ensure that the '4 rights' are met. Detailer decisions are primarily subjective and may not always result in the best match for the Navy and/or the sailor. Detailers must consider numerous, often changing, policies and procedures promulgated by DoD, CNO, MCA, and CNP when matching personnel to billets. When making assignments, the detailer must also consider PCS cost, fleet balance, requisition priorities, gapped billets, sea/shore rotation, pay grade, gender, and number of family members. Detailers continually struggle to manage the Navy's requirements with the sailors' wishes and mistakes are easily made. CCCs, who act as filters, limit applications to only those who qualify for the job, may make mistakes. As CCCs have to deal with a wide range of ratings and NECs, they may not have the experience or knowledge to accurately filter out those sailors who do not qualify for a job or to identify the best career choice for the sailor. The experiences of different CCCs are subjective, highly variable, and depend on what they experience in their own careers. CCCs also have to keep up with the numerous changes in career management policies. They may not see these policies or forget them. Large volumes of references and career guidance material in various formats and binders serve as guides for CCCs to refer to. However, they are inconvenient to refer to and have to be manually updated as policy changes constantly.

Sailors Needs and Preferences Are Not Met. Another problem with the distribution process is that the sailors' needs, wants and desires frequently take a back seat to the Navy's needs. Acting in part as Career Counselors, the detailers must advocate various duty assignments for service members. The detailer must ensure that personnel have the opportunity for advancement experience and rating excellence. This

is done even if sailors make informed decisions to forgo assignments that ensure the above in exchange for assignments that jeopardize their careers and advancement opportunities but meet other preferences that they consider more important. For example, a sailor may know that he/she will be leaving the Navy after their next assignment. Their assignment preference would then prioritize other job aspects, such as meeting the preference for family needs or location.

<u>Perceived as Subjective by Sailors and Commands</u>. Despite the changes in the process and the improvements introduced by JASS, sailors and commands continue to perceive the process as being subjective. Sailors believe that not all jobs are displayed on JASS and that the detailers 'hold' the best jobs for their friends and acquaintances. Commands perceive that the allocation process is paramount to the political aspirations of the individuals making the decisions. The commands feel their true needs and desires are not fully considered. For example, the individual commands may prioritize a sailor with an excellent performance record over one who has the specific training. They may believe that they can use on the job training to train this individual as long as he/she is a top performer.

<u>Labor Intensive</u>. The entire distribution process is extremely labor intensive. There are over two hundred detailers constantly at work manually matching sailors to billets while balancing a plethora of needs within a short timeline. There is a CCC for every ship and shore command with the responsibility to counsel every single sailor in the command. This includes checking up on backgrounds, manually finding suitable career paths, looking up available jobs in JASS, reading up on policies, and finally counseling the sailor. Placement officers also work constantly to represent commands' needs and provide feedback to commands on the resource constraints. There are many phone and e-mail exchanges between sailors and detailers, and detailers and placement officers involving negotiations, explanations and even some 'horse trading'. With the introduction of new systems which are frequently incompatible with existing legacy systems, the process is not seamless and data have to be manually transferred from one system to another. One example of such incompatibility, which increases the amount of

labor involved with the process is the incompatibility of JASS and EAIS. Detailers must laboriously hand-transfer information from JASS into EAIS, and vice versa.

Long Cycle Times. The cycle time for the process is extremely long. Sailors start to look for assignments, or will be looked at for assignments, nine months prior to their planned rotation date (PRD). The entire process can take five to nine months with sailors receiving written orders anywhere from five months prior to three months after their PRD. This is largely due to the discussions between the sailor and detailer and the detailer and placement officer that can go on back and forth for a few months until both parties are satisfied the options. This affects sailors' ability to schedule and prepare their family for a move.

Sailors Engage in Gaming Activities. The current process allows for gaming activities by the sailor. The sailors know that the process runs in two-week cycles. If the sailors do not see jobs that they want on JASS, they have the option to do nothing and wait for the next cycle with the hope that the next batch of available jobs will contain jobs they want. The problem with this behavior surfaces at six months prior to their PRD, where the detailer has the option of assigning a sailor without the sailor's input. Another gaming procedure is common among individuals who are coming to the end of their EOS requirement. These individuals do not show up on the list of distributable personnel. Therefore, their names are not in the system. Some of these individuals delay the extension or reenlistment process while waiting for their preferred duty stations to materialize. The longer these individuals wait, the longer the process tends to be as these individuals need to be processed through the entire system manually. Decisions about where to assign them are also held in abeyance until the sailors decide to stay or leave the service, and this adds to the detailers' workload. It also reduces the available resource pool for assignment, reducing the possibility of better matches.

Redundancies in the Process. The current process hinders efficiency by building in redundancy. For example, detailers filter sailors' qualifications to fit the billets' requirements, account for sailor preferences and career goals, and balance the needs of

the Navy. The sailors look at the available job listings in JASS (which lists the Navy's requirements) and decide on the jobs for which they want to apply. The career counselor then looks at the sailors' decisions and 'guides' them onto the right path for their Rating/NEC and career progression. The detailer looks at the sailors' requests and makes assignments based on the many organizational constraints and the sailors' best interest (preference, career progression). Last, but not least, the electronic assignment is sent to EPMAC, where yet one more individual looks them over 'in the interest of the sailor' and verifies that a qualified sailor is assigned to the billet. Four separate individuals are tasked with looking at the same issue of making sure a qualified sailor is assigned to the billet and that it will ensure a career progression in line with policy.

B. REVIEW OF ENABLING TECHNOLOGIES

The rapid advance in information technologies has permeated through the Navy in all its operations. Many of the latest algorithms, resource distribution models, and knowledge acquisition and delivery architectures that are used for scheduling, assignment, transportation and resource allocation can be used for distributing scarce sailors to billets. To date there is encouraging research on some of these technologies that can be used to propel the distribution process to a higher level of efficiency and effectiveness. This section describes some of these technologies that are considered for the redesign process.

1. Two-Sided Matching Algorithm

In the case of the Navy's distribution process, a two-sided matching algorithm considers both the commands' and sailors' ranked list of preferences for each other. A complete description of the algorithm can be found in Robards' (2001) paper "Applying Two-sided Matching Process to the US Navy Enlisted Assignment Process" and Ng and Soh's (2001) paper "Agent Based Simulation System: A Demonstration of the Advantages of an Electronic Employment Market in a Large Military Organization." Extracted from Ng and Soh's paper, a short description of the algorithm is in Appendix 1.

Using this algorithm, Robards (2001), Ng and Soh (2001), and Gates and Nissen (2001) conducted a series of research analyses and experiments to establish the utility and characteristics of sailor-billet matches in the context of the Navy enlisted assignment process. In general, the papers find that the two-sided matching algorithm, if used in the Navy's distribution process, can yield significant gains in total satisfaction. In particular, the following results will play an important role in the redesign process:

Increased Consistent Total Utility. Gates and Nissen compared results of 10 sailors matched to 12 Jobs using the two-sided algorithm and experiments of matches done manually by human subjects. They found that, on average, a command biased algorithm yielded matches that had largely similar utilities for commands as those completed by human 'detailers.' However, the two-sided algorithm concurrently yielded a significantly higher utility for sailors. This shows that two sided matching could improve sailor satisfaction without sacrificing command requirements and satisfaction. The extreme variability in the detailers' matches showed that the human detailers ability to match sailors to jobs varied widely according to expertise, and that they can easily become overwhelmed by the complex web of details, whereas the two sided algorithm performed well with much detail.

Benefits in Increasing Matching Intervals and Preference Lists. Ng and Soh (2001) conducted a study based on a simulation model they constructed. They found that longer intervals (8 weeks cf. 2 weeks currently) between matches could reap higher quality and quantity of matches as there are more sailors and billets to choose from. Two-sided algorithms can overcome the human constraints associated with too many sailors and billets to match over a longer interval between matches. However the larger pool must also have longer preference lists to reap these benefits of scale. For a two-week interval, optimal preference list lengths should be 3 for higher priority billets and 9 for lower priority billets. This compared to an optimal preference list length of 14 for higher priority billets and 33 for lower priority billets with an 8-week interval. However, there may be difficulty for sailors to list more than 5 billets as they have to mentally juggle too many considerations in order to rank list so many options. Here, there is scope for an

intelligent software agent to assist them in ranking their options based on a set of user stated sailor and billet attributes.

Ability to Concurrently Balance Commands' and Sailors' Needs. Ng and Soh also found that there were no significant differences in command and sailor utilities regardless of whether a command biased or sailor biased algorithm was used. This implies that the algorithm is useful in balancing the needs of both commands and sailors.

Modifications in Two-Sided Matching Process to Fit the Navy's Context. Robards examined the application of two–sided matching algorithms in the Navy enlisted assignment process and the unique issues it presents. He identified that a direct application of the algorithm is not desirable as there are unique problems in this case. These issues include potential instability in the matches due to a fixed assignment period, and potential of gaming behavior when the market is not cleared prior to the next round of assignments.[2] The inability of the algorithm to ensure that all sailors are assigned, and that priority billets are filled (especially undesirable billets), requires modifications in the assignment process.

To alleviate these problems, Robards proposed several modifications to the assignment process. First, he proposed that the matching cycle of the assignments should be lengthened to increase the pool of sailors and billets leading to better quality matches. Second, he proposed that sailors be given some flexibility in deciding when they move between billets to alleviate the problem of unstable matches due to a fixed PRD. Third, priority billets could be filled (matched) by either matching them first, manually manipulating the conventional matching results after completing the matching process, or relying on multiple rounds of matches to increase their chances of getting matched. Finally, Robards proposed that incentives be provided to encourage sailors to include less

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[2] When the market is not cleared, not all sailors are matched and hence have to be carried over to the next matching period. This may encourage gaming behavior if sailors purposefully hold out on ranking their options until future rounds when they might find billets they refer. This will decrease the number of available sailors in earlier rounds and lower the quality and proportion of matches, though this effect may balance out as this repeated process reaches steady state.

desirable billets in their preference lists to increase their chances of getting matched.

These issues identified by Robards, Ng and Soh, and Gates and Nissen are considered holistically when the two-sided matching algorithm is integrated into the redesigned distribution process. Prima facie, the two-sided matching algorithm appears to be a promising change lever to dramatically improve the distribution process, subject to some modifications.

2. Optimization

Optimization algorithms and models find the best solution for an objective function subjected to a set of constraints. Optimization works only if the problem is structured and deterministic. It requires precise input data, the desired output and the mathematical inter-relationships between the two. Although the enlisted distribution problem is a semi-structured problem, it can be decomposed to smaller parts that may be able to use optimization models. Detailed here are descriptions of how the US Army uses optimization to assign its soldiers, and cutting edge software and optimization algorithms that may be useful to the Navy's assignment problem.

a. The US Army's EDAS

<u>Description</u>. The US Army currently uses an optimization process to match soldiers to billets. After requisitions are generated, the matching process takes place using the Enlisted Distribution Assignment System (EDAS). Wasmund (June 2001) provides a concise description of the Army's detailing process for enlisted soldiers.

> EDAS matches available positions, nominates those who are the best qualified, enables assignment managers to verify nominated soldiers and issues instructions to verified soldiers….EDAS is an automated nomination and assignment procedure that compares

qualitative requirements recorded on requisitions against selected qualification factors for each soldier. Some of the major qualifications considered include grade, MOS and skill level, Skill Qualification Identifier (SQI), Expiration Term of Service (ETS), months since last PCS and/or months since return from overseas (to ensure stabilization), soldier's availability month compared with requirement month, and, finally, the soldier's area of preference. Each soldier is compared to each requisition and given a numeric score for every requisition for which he or she can be nominated. Comparing the requisition's qualitative requirements and the soldier's qualifications derives scores. Once every soldier's record has been reviewed and points have been awarded for a qualitative match to each requisition, a group of nominations is selected that provides the best overall requisition match in terms of quantity and quality. Assignment preferences of the soldier are considered, but the needs of the Army are given primary consideration. Soldiers are assigned to their preference only if the needs of the Army can also be served.

The nomination procedure in EDAS has three basic goals. First, each valid requisition will have at least one soldier nominated to it, provided sufficient soldiers are available for assignment. Second, requisitions will be filled by relative priority. When a shortage of soldiers exists, the shortage will be shared proportionately by all requisitioning activities according to priority. Finally, soldiers will be nominated to an assignment for which they are qualified. Assignment managers at PERSCOM verify nominations produced by EDAS, and after reviewing all available information, either accept a soldier for the assignment or reject all nominees and return the requisition to the selection process for new nominations. Qualified individuals may also be selected manually to match the

requisition regardless of a nomination by EDAS.

Conceptually, the process described above is an optimization process. First, soldiers' attributes are matched against job requirements and quantified (scored) depending on how well they fit the requirements. The result is a ranked list of soldiers who meet each job's requirements. As resources are scarce and a soldier may be ranked the same for two different billets, the process optimizes the best mix of matches between soldiers and billets to maximize the total score for the entire group. Each billet may not get its highest ranked soldier, but the system as a whole has the highest possible total score for all the matched billets. This resembles a one-sided matching process that is used to optimize utility for the commands but not the sailors.

Applicability to the Navy. It is noted that the Army's process ensures all soldiers who are nominated (and ranked) for each billet qualify for that billet. Also, preferences of soldiers are taken into consideration, although preferences are low in the pecking order of considerations when detailers assign soldiers to billets. The Navy can possibly adopt this process, as considerations for detailing are largely (but not completely) the same between the two branches. The Navy can adopt such an optimization system on top of its current process of using career counselors to screen and advise sailors before they apply for billets.

b. General Algebraic Modeling System (GAMS)

Description. The General Algebraic Modeling System (GAMS) is a popular commercial software specifically designed for modeling linear, nonlinear and mixed integer optimization problems. GAMS is especially useful for handling large, complex, one-of-a-kind problems that may require many revisions to establish an accurate model; much like the Navy's detailing problem. The system models problems in a highly compact and natural way. The user can change the formulation quickly and easily, can change from one solver to another, and can even convert from linear to nonlinear with little trouble. GAMS is available for use on personal computers,

workstations, mainframes and supercomputers. GAMS allows the user to concentrate on the modeling problem by making the setup simple. The system takes care of the time-consuming details of the specific machine and system software implementation.

GAMS lets the user concentrate on modeling. By eliminating the need to think about purely technical machine-specific problems, such as address calculations, storage assignments, subroutine linkage, and input-output and flow control, GAMS increases the time available for conceptualizing and running the model, and analyzing the results. GAMS internally structures good modeling habits by requiring concise and exact specification of entities and relationships. Models are described in concise algebraic statements which are easy for both humans and machines to read. Whole sets of closely related constraints are entered in one statement. GAMS automatically generates each constraint equation, and lets the user make exceptions in cases where generality is not desired. Statements can be reused in models without having to change the algebra when other instances of the same or related problems arise. GAMS also handles dynamic models involving time sequences, lags and leads and treatment of temporal endpoints that may be encountered in the Navy assignment problem. Models are fully portable from one computer platform to another which is useful considering the Navy's varied legacy systems and the need to integrate the redesigned DSSs with current systems like EAIS and TFMMS. GAMS facilitates sensitivity analysis and the user can easily program a model to solve for different values of an element and then generate an output report listing the solution characteristics for each case.

<u>Use of GAMS in the SAF</u>. The Singapore Armed Forces (SAF) currently uses GAMS as the engine in its manpower computer systems to distribute conscript servicemen to the various vocations (or MOSs) like Infantrymen, Technicians etc. The system optimizes the match of soldier attributes to the commands' requirements to ensure manning priorities are met with the appropriate quality and quantity of soldiers. GAMS helps in matching close to 4,000 soldiers every quarter to some 50 MOSs subject to manning constraints and priorities, medical and physical fitness requirements, educational and psychological profiles, and distance of the soldiers' home to the

command. GAMS allows the flexibility to easily change the optimization model as policy changes (often) and to make exceptions to the general rule. For example, suppose that the manning target for Commandos is 150%, and there is a shortage of soldiers who meet the Commando corps' requirements. GAMS will recognize this as shortage of resource and work around this resource constraint to get as close as possible to the target manning.

Applicability to the Navy. GAMS can serve as a useful component in DSSs in the Navy assignment process as the process is dynamic, complex and requires the flexibility that GAMS affords. The main strength of GAMS is that it is easy to use, flexible enough to modify the model to reflect policy changes (e.g. manning priorities and targets), able to recognize exceptions to the general rule, and handles many constraints and variables.

c. Genetic Optimization Algorithms

Description. Genetic algorithms follow steps inspired by biological organisms where better and better solutions (species) evolve from the previous generations of solutions until an optimal or near optimal solution is reached. This method is very powerful as it *learns* by taking feedback from the process and reproduces new solutions that take a step closer to the optimal solution. Inferior solutions are discarded and superior ones accumulated, thus allowing the system to learn about its environment. They have the ability to solve complex dynamic optimization problems quickly, and to solve problems that may not be solvable by conventional optimization algorithms. Current examples of commercial Genetic Algorithms include assembly line balancing, and scheduling activities.

The problem must first be described in mathematical terms and a solution represented by a binary solution string. A 'fitness function' must also be established against which the solution string can be judged. An initial set of solutions is generated and compared against the 'fitness function.' Only the fittest (best) of these solutions is retained, and weaker ones are eliminated. Offsprings which differ from their parents are

generated by a ‘crossover’ action where a solution string is divided at a random point and crossed over with another string to produce two new offsprings. Constraints specified in the algorithm limit the variability of the solutions generated by discarding those solutions that fall out of the constraints’ limits. Surviving offsprings are then compared against the ‘fitness function’ and the best solution kept. Since only the best solution in each iteration is kept, the process will generate solutions that get closer and closer to the ideal. This iterative process continues until an optimal or good enough solution is found. Genetic algorithms also learn by taking feedback from the ‘fitness function’ and generate ‘stronger’ solutions than its parents. Importantly, this allows it to alter solutions generated merely by changing the ‘fitness function’ and the constraints.

<u>Applicability to the Navy</u>. In the Navy assignment process, the ‘fitness function’ can be defined as the total score of sailor-billets matches when sailors’ attributes are compared to the billets’ requirements. A solution string represents a set of sailor-billet matches, with the score for each set dependant on how well the sailors meets the billets’ requirements. The goal is to find a set of sailor-billet matches that optimize the total scores. Constraints could include the need to fill all priority one billets to 100% (i.e. no priority one billets should be left unmatched). A genetic algorithm will generate solutions that represent different sets of sailor-billet matches. Weak (low scoring) solutions and those that do not fulfil the constraints (do not assign sailors to all priority one billets) are discarded and new solutions (offsprings) generated from the strong (high scoring) solutions, until there are no other solutions that offer a higher score. The process can take feeds from TFMMS that informs the process of the current manning level for each rating. The process can take this information and dynamically produce solutions that aim to fill these ratings to their target levels. A detailer can alter the ‘fitness function’ with heavier weights on PCS costs for example. This will alter the scores of sailor-billet matches to produce different solutions. Similarly, constraints can be added or changed and the process will alter solutions to find the best solution. Including additional sailors and billets during the iterative process will also dynamically shift the solutions produced quickly. This allows detailers to deal with ad hoc inclusions of billets required and sailors distributable within a two week detailing cycle, without the needing to manually match

them or delay them to a later cycle.

3. Intelligent Agents

Description. Intelligent agents are software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in doing so employ some knowledge or representations of the user's goals or desires. (IBM, www.ibm.com). Nissen (2001) classifies intelligent agents into four main classes. In increasing order of sophistication and intelligence, these classes comprise:

- Information filtering agents which rely on user inputs to filter out or sort text, e-mails, network news groups postings and FAQs.

- Information retrieval agents focus on collecting and summarizing information from distributed sources, subject to the requirements input by the user. Examples include shopping 'bots', web robots and publishing tools, and assisted web browsing.

- Advisory agents provide intelligent advice by recognizing patterns, deciding what information is needed, retrieving information from distributed sources and then making recommendations to the user. They may even learn from the environment and improve intelligent capabilities with continued use. Examples include e-concierge services, shopping websites that recommend products, buyer/seller match making advice, and military reconnaissance support.

- Performative agents draw from the capabilities of the other 3 classes. Importantly, they are sophisticated enough to make autonomous decisions on their own to change the environment and execute transactions with external parties on behalf of their users. Examples include digital library

services, auction marketspaces, agent negotiation, and scheduling functions.

Applicability to the Navy. Intelligent software agents can sieve through large amounts of data and organize them into a useful summary that users can digest and act on. They can reach many distributed sources of information more quickly then is for a human agent. They can also automate many labor and information intensive tasks that may require some level of interaction with the user. This frees the user to make well informed and timely decisions. Intelligent agents are useful technology for the Navy distribution process where there are many commands, sailors and policies to guide their allocation. Intelligent Agents have the potential to improve the detailing process drastically by efficiently and accurately dealing with large amounts of sailor and command attributes, interactions with sailors and placement officers, and enlisted resource allocation policies and targets. Prima facie, Performative agents, with their ability to represent both sailors' and commands' needs, and perform binding transactions between them, may even eliminate the need for human detailers and placement officers.

Intelligent Agents in the 'Personnel Mall' Concept. Gates and Nissen (2000) developed a proof-of-concept electronic marketspace for sailors and commands called the Personnel Mall. It employs intelligent agent technology to represent commands' and sailors' needs. The Personnel Mall uses a shopping mall metaphor to describe how employee/employer matching is conducted in this electronic environment. Commands (shoppers) look for appropriate sailors (sellers) to fill their requirements. Neither commands or sailors need to know in detail or in advance what other commands or other sailors are available. However, sailors and commands can register their job openings in 'yellow pages' and 'white pages' respectively to help identify desirable matches. The intelligent agents in the personnel malls possess the capability to autonomously search and match on behalf of commands and sailors. Both commands and sailors need to input their requirements into the web-based interface. Thereafter, the intelligent software in the Personnel Mall takes over and matches sailors to billets according to a set of policies, comparison of attributes to requirements, and preferences. A two-sided matching

algorithm or optimization algorithm can be used to perform this matching, where a ranked list of sailors by commands is matched with a ranked preference list of commands by sailors. Intelligent sailor and command agents will represent their needs in this matching process by using the requirement and preference inputs given to them when they decide to participate in the assignment process. The agents then communicate back to the commands and sailors the outcomes of the matches, negotiate the details with them, and eventually finalize the match by documenting it and issuing assignment orders.

Intelligent agents perform several intelligent, autonomous routine tasks for commands and sailors In the Personnel mall concept. They retrieve, filter and organize available billet and sailor information for commands and sailors based on their requirements and eligibility, which assist sailors and commands in making preference choices. They advise sailors and commands on their best match given the current demand, supply and policy constraints, and receive inputs from them for another iteration. Finally the agents formalize the matches by documenting them and issuing assignment/PCS orders. The Personnel Mall does all of this in lieu of a human detailer, who today has to juggle and balance all sailor, command and policy needs manually.

4. Knowledge Based Systems

Description. Knowledge Based Systems (KBS) are decision support systems that employ knowledge that is captured in a computer system to assist in decision making. Expert systems (ES) fall under this category where they have detailed knowledge that is not widely distributed in a particular area of interest. Although KBS and ES are often used interchangeably, Turban and Aronson (2001) suggest that KBSs use explicit knowledge that is published whereas ESs use explicit knowledge as well as tacit (undocumented) knowledge that is captured from human experts. An example of KBS are automated help desks whereas consultancy systems that can configure complicated computer systems are better described as ESs. KBSs are more easily constructed when the knowledge is readily available in well documented form, whereas ESs require a more detailed extraction of knowledge from human experts that is costly and time consuming.

KBSs employ not only traditional numeric rule based processing ability, but also the ability to manipulate symbolic information. KBSs can also use heuristics to process symbolic information, use inferencing and reasoning abilities, and pattern matching techniques to link information provided by the user to a knowledge base and models in the system's model base. Outputs based on the user fed information, process models, and knowledge base relationships are then produced that can interpret information, predict future events, diagnose problems, design solutions, plan alternatives, monitor processes for exceptions, instruct (teach) a user/learner and control a process.

KBSs/ESs collect and share valuable knowledge across the organization. They enhance the decision makers' ability to make complex decisions that involve intertwined policies, objectives, and client information. KBSs also allow updating the knowledge base of policies and knowledge changes at source, as compared to the traditional distributed methods via memos and e-mail that may not be read by the all affected decision makers. ESs also capture scarce tacit expertise that resides in experts and shares it with other users; knowledge still resides in the organization even if the expert leaves the organization.

The three major components of a KBS are the knowledge base which contains the knowledge itself, the inference engine that relates the user inputs to the knowledge base and provides a reasoning methodology, and the user interface which allows users to easily input their queries and receive answers.

Applicability to the Navy. In the Navy enlisted distribution process, command career counselors (CCC) guide sailors on career choices based on career path guidelines for their rate/ratings, past performance, manning and assignment policies, availability of training opportunities and billets etc. In fact, CCCs must have broad and detailed knowledge of all these policies, how they apply to the ratings, dynamic changes in opportunities, and the characteristics of their sailor wards. All this knowledge is dynamic and changes constantly, making it hard for CCCs to keep up and make consistently

accurate recommendations to their wards. Currently, CCCs have to refer to varied sources for this information; JASS for billet openings, career manuals for career path information, enlisted master file for sailor information, policy memos for updated policies, etc. Some of this knowledge is also tacit and more experienced CCCs can 'better work the system' than others. Sharing this knowledge would be in the best interest of the sailors. Given the capabilities of KBSs/ ESs today, there is a promising opportunity to use KBSs/ESs to assist CCCs in better career counseling. Updated knowledge and information from all the distributed sources and personnel systems can be collated into one source that resides on the CCCs' desktops. These can be combined with tacit knowledge from experienced CCCs on how to deal with problematic sailors, sailors with special requirements and requests, and contacts with external agencies like training institutions and detailers, etc.

5. Web Based Technology –The Navy / Marine Corps Intranet (NMCI)

Description. Web based technology is used to enable the geographically distributed Navy commands to communicate seamlessly. The Navy Marine Corps Intranet (NMCI) is a comprehensive, enterprise-wide initiative that will make the full range of network-based information services available to sailors and Marines for day-to-day activities and in war. When initial operating capability is achieved by the end of 2001, NMCI will give the Navy and Marine Corps secure, universal access to integrated voice, video and data communications. It affords pier-side connectivity to Navy vessels in port and links more than 360,000 desktops across the United States as well as sites in Puerto Rico, Iceland and Cuba. NMCI will apply the speed and might of world-class Internet technology to everything from administrative tasks to ammunition supply. It will help the Navy and Marine Corps meet the following critical objectives: enhanced network security, interoperability with CINCs and other services, knowledge sharing across the globe, increased productivity, improved systems reliability and quality of service, and reduced cost of voice, video and data services. (www.eds.com/nmci).

Applicability to the Navy's Distribution Redesign Process. This organization wide

intranet facilitates the implementation of Navy wide applications that reach the far flung dispersion of Navy operations. Riding on this infrastructure, DSSs that support the enlisted distribution process can then reach virtually all sailors who have access to a computer terminal that is linked to the NMCI. Critical to the success of this process is ensuring all sailors have an equal chance of expressing their preferences for their next assignment, and to access information before they make that decision. By supporting legacy systems, the NMCI also allows the development of new applications that integrate legacy systems (e.g. TFMMS, EMF). These DSSs will exploit the critical objectives of the NMCI described above. Development time and costs will also be reduced as the content delivery network need not be built from scratch but instead ride on the existing NMCI network. In short, NMCI possesses the infrastructure on which DSSs can be built and implemented to support a redesigned enlisted distribution process. However, the DSSs to be developed must also use the NMCI required networking and security protocols.

C. SWOT ANALYSIS

This chapter has described the current distribution process and the possible technological tools available to improve it. Integrating the technology into a redesigned process requires a detailed understanding of the potential impact the technology will have on the redesigned process. A Strength, Weakness, Opportunities and Threats (SWOT) analysis is conducted to examine the internal and external technological factors and processes that may hinder or promote improving the Navy enlisted distribution process. A detailed analysis of this nature helps identify the technological ‘push’ and ‘pull’ forces that can drive the distribution process and leverage the redesign process. Strengths and Weaknesses refer to the internal factors in the Navy that promote or hinder the redesign process, whereas Opportunities and Threats refer to external factors.

1. Strengths

The current distribution process has some good features that a redesigned distribution process should retain or build upon.

Existing Legacy Systems Provide Some Form of IT Support and Data. Existing data pools in the EMF and TFMMS, and DSSs like JASS, EDPROJ, and EAIS, can be harnessed and integrated into a holistic system subject to compatibility issues. Any new DSSs or data requirements to support the new process need not be built from the ground up. However, the new system(s) need to be well integrated, seamless and easy to use.

Sailors' Preferences Solicited. Formally soliciting sailors' preferences and taking them into account in the assignment process is currently an entrenched practice in the Navy. Traditionally, military institutions have shunned this approach as the culture of "duty before self" usually reigns. The Navy has taken a bold approach to implement this practice to improve sailor motivation and retention. Therefore, implementing a process to use two-sided matching where sailor preferences are important would face few objections from the Navy.

JASS – Valuable Tool to Inform Sailors. In its current form, JASS already serves as a useful IT tool to facilitate the process of informing and collecting sailors' preferences. The familiarity of JASS to its users (CCCs, placement officers, and Sailors) will allow it to serve as a platform for further enhancements to better educate, and inform its users of billet requirements and collect detailed sailor preferences. A system need not be built from scratch but rather enhancements be made to the current form of JASS.

Human to Human Interaction Promotes a Perception of Care. Human interaction, especially between sailors and CCCs, and sailors and detailers, is a key feature of the current process. Through this human interaction, a paternalistic culture is promoted where the organization, through its proxies (CCCs and detailers), shows that it cares for every sailor's welfare. Through this human interaction, verbal and non verbal cues enhance the communication of both facts and emotions; both of which feature strongly in

the discussion on career moves that impact the sailors' career and personal life. Through human interaction, these exchanges between sailors and both their CCCs and detailers make the sailor feel that a person of some influence is personally looking out for them. This is observed in the current process where sailors still insist on talking to their detailers, although much of the information is already on JASS. As much as possible, this human to human interaction should be preserved and not be completely substituted by a cold, albeit 'know all', computer system.

2. Weaknesses

Apart from the shortcomings of the distribution outputs described earlier, the weakness of the current system and available technology is described here. These shortcomings should be overcome in the new process design.

<u>CCCs Not Well Supported with Tools</u>. CCCs may receive training for their roles and updates on changes in policies. However, with the number of ratings, MOSs and NECs in the enlisted community, it is difficult for CCCs to keep track of all the changes in the entire enlisted community. CCCs have to refer to varied sources of information found in manuals, memos, e-mails and online systems (eg. JASS, EMF). CCCs often have to call their peers or community to clarify any doubts, which is time consuming and may not yield the most accurate information. There is scope to better equip CCCs with a single source of information that is up to date and can answer to all career counseling needs.

<u>No IT Support for Placement Officers</u>. Placement officers currently do not have any IT systems to assist in representing commands' needs to the detailers. Most of the interactions occur over the telephone and requests are often unstructured. Ad hoc global changes in requirements within a command (e.g. a sudden order for a ship to be deployed) will require the command's placement officer to individually call all the detailers of all the affected ratings within the command. Placement officers also have to talk to the detailers to state the sailors' attributes that they desire (e.g. experience level,

exceptions to eligibility criteria, etc.). This is laborious, time consuming and may not be effective in representing the commands' requirements. There is scope for an IT system where placement officers can input their commands' detailed requirements and detailers' requisition systems can be updated accordingly. Such requests can be ad hoc requests during a cycle that can be dynamically included into the pool of billets and will include details of sailor attributes.

JASS Does Not Detail Sailors' Eligibility. JASS lists the jobs available to all sailors. However, JASS does not filter out those jobs for which a particular sailor is ineligible. For that, sailors have to refer to their CCCs, who manually filter out inappropriate jobs. This is time consuming and prone to mistakes.

JASS Not Well Integrated with EAIS. The varied IT systems in place now are not well integrated. One example is the incompatibility between JASS and EAIS. Detailers must laboriously hand-transfer information from JASS into EAIS, and vice versa.

Dynamic Inclusions Held Off Till Next Cycle. As the process follows a two-week cycle, new information that arises during the cycle has to be held off till the next cycle. Billets that are gapped during the two-week cycle can only be included as requisitions at the next cycle. Inventory that becomes distributable (e.g., a sailor at EOS decides to reenlist) during the cycle is not considered until the next cycle. This potentially reduces the pool of billets and sailors that can be matched and thus limits the choices for both commands and sailors. Better matches might result if such 'late inclusions' were considered for matching in the current cycle. If the process were lengthened, to say a four-week long cycle, to increase the pool of billets and sailors, the inability of the current process to incorporate late inclusions will cause them to be delayed by a longer period.

Current 2-week Cycle Has Too Few Jobs Options and Encourages Gaming. The current process relies on detailers manually matching sailors and billets. The cycle is restricted to two weeks in part to limit the number of sailors and billets that need to be

matched so that detailers are not overwhelmed by too many details. Even then, detailers have deal with 45 sailors and 60 billets per average 2-week cycle. This also limits the quality of matches as the choices for billets and sailors are reduced. Sailors and placement officer who see that there are no billets or sailors they prefer may hold off their decisions until the next cycle when more sailors and billets turn up (i.e. gaming). This will delay the assignment cycle and cause cases to backlog, perhaps to an extent that detailers may find hard to clear. To prevent this, detailers try to persuade sailors to accept jobs, and commands to accept sailors that are not good matches, just to clear the pool. This leads to sub-optimal matches; commands and sailors mismatched. By employing matching technology to automate the matching process, the time between requisition cycles and hence the resource pool can be increased to improve the quality of matches and reduce the possibility of gaming.

3. Opportunities

The technologies available present many design opportunities that enable automation, better quality matches, and savings in time and labor. Specific areas where these new technologies can be applied to improve the process are identified here.

<u>Optimization: Matching Attributes to Billets' Requirements – Shortlisting</u>. Optimization technologies facilitate matching sailors' attributes to the billets' requirements, producing ranked lists of preferences between sailors and commands. A ranked shortlist can be produced where sailors who are not eligible will be filtered out. The remaining sailors who are shortlisted can be optimally ranked by how well they fulfill the billets' requirements. This provides sailors a list of jobs for which they are eligible and a ranked list of command preferences to allow two-sided matching to be applied to the assignment process.

<u>Two-sided Matching: Sailors' Preferences Can Be Met Without Sacrificing Commands' Needs</u>. With two- sided matching, sailors' preferences can be met without sacrificing commands' needs. As Ng and Soh (2001) found in their simulation analysis of

the Navy enlisted process, a command biased match produces matching sets that are largely the same as sailor biased matches. This similarity will be further enhanced if sailors make educated choices that also take into account the billets with which they stand the best chances for a match (i.e. make realistic choices). However, in two-sided matching, commands may not get the best man for the job. The best man for the job is defined here as one who has the highest score in the billets' ranking of sailors. In two-sided matching, sailor preferences are considered. As such, billets may not get their highest ranked sailors if the sailors do not rank a billet, or give it a low ranking in their preference list. Therefore, billets may end up with sailors who fulfill their 'Must Have' criteria, but may not have scored highly in the 'Should Have' criteria. This problem can be mitigated if sailors are given information to make educated choices based on their rankings by various commands.

Roth and Peranson (1999) noted the high quality and proportion of matches in a national physician residency matching program. They concluded that the two sided matching algorithm was very successful in matching residents to hospitals because there was a prescreening process that filtered out hospitals for which residents were ineligible, given their background attributes. Residents could then make educated applications to hospitals into which they had a good chance of being accepted.

<u>Knowledge Based System: Ability To Collate Large Amounts Of Information Into Useful Career Management Knowledge for CCCs</u>. The technologies presented earlier enable large amounts of information to be collated into knowledge that can be more easily digested and used by sailors, CCCs and detailers. For example, CCCs have to consider the varied and changing policies in career management, manning requirements and sailor attributes in order to properly counsel a sailor. A knowledge-based DSS can integrate all these related components and propose a career move for the sailor.

<u>Dynamic Updating of Policies</u>. If smart decision support systems are used to facilitate the distribution process, policies can be updated at source in these systems. The latest policies will then be implemented immediately in the distribution process without

fear of human error. In producing their outputs, these DSSs will always use the most current policies, even if the human users do not yet know about them. Although users would still need to be informed of policy changes, the accurate execution of these policies would be assured if decisions were made with the output from DSSs. In fact, a pop up screen can inform users of any changes in policies as they occur. In particular, policies can be updated in a sailor screening (eligibility) system, career counseling system, and sailor-billet matching system. The inefficiency, complexity and uncertainty of updating detailers and CCCs via memos and expecting them to execute the latest policies accurately can be avoided if they all use a common DSS that is dynamically updated as policy changes occur. For example, a change in career path policy for a particular rating can be updated in a knowledge based DSS that CCCs use to counsel sailors. The system can intelligently take this new policy into account when producing career advisories. CCCs can also be alerted to the change via a pop up screen.

Dynamic Inclusion of Billets. With genetic optimization algorithms, as billets become available, they can be included in the billet pool. New optimal lists can be easily produced after including new inputs. They need not wait till the next requisition cycle to be included. However, the process of how to control for such inclusions and how to inform sailors of new billet inclusions must be considered. If sailors were to list their preferences by listing attributes they would like to see in their next assignment (and not by stating exact billets) and get matched to billets with those attributes according to that list, then even late inclusion of billets can be considered.

Systems Can Learn and Improve. With the latest technologies now available, systems have the ability to learn about their environment and improve their problem solving abilities. This will allow them to make recommendations that more accurately reflect the conditions and commands' and sailors' preferences. Such systems can employ artificial intelligence technologies to perform better optimization problem solving routines, collect information about career counseling knowledge, infer sailors' and commands' preferences and needs, and employ heuristics to better match sailors to billets.

Ability To Automate Tedious Repetitive And Complex Tasks. Using the technologies described in this paper, the Navy can automate the repetitive, tedious and yet complex tasks in the distribution process. This has the potential to reduce mistakes, cycle times, and labor requirements.

NMCI Infrastructure Facilitates System Integration. The Navy Marine Corps Intranet infrastructure allows Navy wide applications to ride on its platform and share its resources. This will allow systems to be implemented more easily and with less time and resources.

Portability of Army's EDAS. The Army's system may be portable to the Navy, albeit with some adjustments. This could reduce development time and costs of a new DSS for the Navy enlisted distribution process.

4. Threats

The limitations of the technologies must also be noted. Blindly applied, these pose threats to the efficiency and effectiveness of the distribution process. The limitations that are of most concerns are discussed here.

Loss of 'Human Touch'. Implementing technology to replace humans poses a threat to the paternalistic culture, in which the Navy prides itself. Smart systems have the potential to interact with sailors and replace the human to human interaction. This turns the process into a 'cold' and business like transaction, which should be avoided. Career counseling entails the power of persuasion that only human CCCs and detailers can perform. The redesign process must consider this and note the need to maintain a human touch to the process.

Difficulty in Capturing the CCCs' Knowledge. To build a knowledge based system, knowledge needs to be captured from the tacit experiences of the experts. In this

case, knowledge about career counseling, contacts and the intricacies of the enlisted career paths need to be captured from the CCCs' minds and organized into a knowledge base, so that an expert system can mimic the decision processes of an expert CCC. This is difficult to achieve given that CCCs have different experiences and may have different views on how to optimize sailors' careers given their circumstances. Relying merely on documented knowledge found in Navy career manuals excludes the wealth of information that CCCs possess.

Sailors make Uneducated Choices. A two-sided matching algorithm will match sailors to billets only if both sides have listed each other in their preference list. In this case, if sailors do not choose their next assignment wisely, it reduces the quality and quantity of the matches. Quality can be reduced if sailors who rank highly on a command's list do not rank the same command highly. A sailor who ranks lower in a command's list may rank the command higher and then be matched to the job. This lowers the quality of match from the command's perspective as it will get a sailor it ranked lower. The quantity of matches may fall if too many sailors list only their 'dream jobs'. The less desirable jobs will not be matched if they do not feature in any of the sailors' preference lists. As such, sailors need to moderate their choices to billets for which they are highly ranked for a two-sided process to work well. Even then, the question arises as to how well is well enough? Regardless, the point is that sailors have to make educated choices; choices for which they stand a chance of being matched. As an analogy, a high school student with a moderate SAT score should not apply to Harvard University. Students need to be educated as to their strength of their SAT scores, so that they can apply to universities that will possibly admit them.

Security. The security of online transactions should be considered. Controls must be introduced to prevent a sailor from sabotaging another sailor. If the distribution DSSs resides on the NMCI, the possibility of external hacking may be reduced, but the system is still vulnerable to internal hacking threats. As the system deals with the careers and aspirations of thousands, data security must be preserved.

D. CHAPTER SUMMARY

The Navy enlisted distribution process is described in this chapter. It consists of three sub processes : allocation, placement and assignment. This thesis focuses largely on redesigning the placement and assignment sub processes. Although the allocation process provides inputs that affect the assignment of sailors to billets, the allocation process can be examined as a stand-alone process. However, references are made to the allocation process where required, and its implications are examined as part of the redesign process. Shortcomings of the current distribution process include not fully meeting commands' requirements or sailors' needs, labor and process inefficiencies, inherent human error and variability, and the perception among sailors and commands that the process is subjective and unfair. The redesign process seeks to reduce these shortcomings.

This chapter also discusses the available technologies that could serve a role as change levers to improve the current process. Promising technology such as two-sided matching algorithms, optimization algorithms and software, intelligent agents, knowledge based systems and web based technologies are examined. If used in tandem with a rationalized process design that leverages on their strengths, these technologies have the potential to make quantum improvements to the distribution process.

A SWOT analysis was conducted to examine the opportunities and constraints of the current process and the technologies presented above. The analysis is summarized in Table 1.

Table 1 – Summary of SWOT Analysis

Strengths	Weakness
• Existing Legacy Systems Provide Some Form of IT Support and Data • Sailors Preferences Solicited • JASS – Valuable Tool To Inform Sailors • Human to Human Interaction Promotes a Perception of Care	• CCCs Not Well Supported with Tools • No IT Support for Placement Officers • JASS Does Not Monitor Sailors' Eligibility • JASS Not Well Integrated with EAIS • Dynamic Inclusions Held Off Till Next Cycle • Current 2-week Cycle Has Too Few Jobs Options and Encourages Gaming
Opportunities	**Threats**
• Optimization: Matching Attributes to Billets Requirements – Shortlisting • Two-sided Matching: Sailors' Preferences Can Be Met Without Sacrificing Commands' Needs • Knowledge Based System: Ability To Collate Large Amounts Of Information Into Useful Career Management Knowledge for CCCs • Dynamic Updating of Policies • Dynamic Inclusion of Billets • Systems Can Learn and Improve • Ability To Automate Tedious Repetitive And Complex Tasks • NMCI Infrastructure Facilitates System Integration • Portability of Army's EDAS.	• Loss of 'Human Touch' • Difficulty in Capturing the CCCs' Knowledge • Sailors make Uneducated Choices • Security

Optimization allows sailors to be screened and ranked according to a set of attributes. This ranked list can later be used for two-sided matching. Intelligent agents can deal with large amounts of data from distributed sources and autonomously represent commands' and sailors' needs to the process. Two-sided matching algorithms can match sailors to billets that take into account their preferences. They can meet sailors' preferences without unduly sacrificing commands' needs, subject to some adjustments to the process. A knowledge based system can assist CCCs in counseling sailors with the latest information available. Finally, all these systems can (and have to be) integrated as a dynamic whole and to function seamlessly. The distribution DSSs can reside on the NMCI infrastructure, thus reducing set up time and costs. This also allows the system to reach all the Navy's distributed intranet users in far flung geographic locations.

Finally, although the technology has the ability to substitute human labor, the 'human touch' must be maintained in the redesigned process. Sailors and commands must feel that they are being looked after by thinking and feeling personnel who they can talk to and trust. This aspect plays an important feature in the redesign process. Technology should be used to enhance the decision making abilities of detailers and CCCs and not replace them.

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III. CRITICAL SUCCESS FACTORS AND CONSTRAINTS

A. DEFINING CRITICAL SUCCESS FACTORS

1. Definition of Critical Success Factors

Critical success factors (CSF) are factors "…that must be considered in attaining an organization's goals….These factors can be strategic, managerial, or operational in nature, and stem from organizational, industrial, and environmental sources." (Turban & Aronson, p. 312). It is important that the CSFs be identified because they serve as beacons to guide the process redesign towards the organization's goals. They are 'must dos' to achieve the overall goals. Ideally, if a CSF can be measured, it can then indicate the success of the redesigned process and the improvements compared to the previous process. The CSFs that are key to successfully redesigning the distribution process are discussed here.

2. *Goals of the Distribution Process*

In the Navy enlisted distribution process, the Navy's goals are two-fold: 1) To ensure that commands get the right person with the right training into the right billet at the right time. 2) Improve job motivation and retention rates among enlisted sailors.

3. Critical Success Factors of the Redesigned Distribution Process

To achieve these goals, the following critical success factors have to be achieved:

- Smooth, timely, complete and accurate information flows.
- Sailors' expectations and needs are managed and met.
- Trust in the objectivity and reliability of the process
- High proportion of matched sailors and billets
- High quality of matches

- Stability of matches.
- Flexibility to deal with exceptions and dynamic changes
- Maintain the human touch.

Smooth, Timely, Complete and Accurate Information Flows. The distribution process is an information intensive process. Much of the process' success hinges on the ability of accurate and complete information flowing smoothly in a timely manner to the users: sailors, commands, CCCs, detailers and process auditors like EPMAC. Information flows include billet information (requisitions, attributes, and requirements), sailor information (availability, attributes and preferences), policies (manning targets, career management policies, reassignment policies), and transactions (preliminary assignments, order writing, audits). This information flows from one part to another and forms a complex web of information creation, integration, and interpretation. The process must be able to handle the heavy information traffic of requests and creation efficiently and securely. The process must also ensure that the information is complete and accurate to reflect the latest policies and list the sailors and billets currently available in the requisition cycle. All users must be able to access the information that they need easily and be confident the contents are accurate.

Sailors' Expectations and Needs are Managed and Met. To motivate sailors, their expectations must be managed. The Navy then has to meet these expectations within limits. The Navy cannot possibly meet all the sailors' unbridled aspiration to be assigned to a 'dream job'. The deviation of sailors' expectation and the eventual outcome will impact their satisfaction over the assignment and ultimately impact their motivation. In the assignment process, it is therefore important to contain sailors' expectations of where they should aim to be assigned to be within reasonable limits. Sailors must be counseled as to which billets they should realistically expect and choose given their background and the Navy's needs. Clear information must be presented that considers their attributes, the available billets for which they are suited, their chances of getting assigned to each of the billets, and their career path and personal needs. Sailors must perceive that they are treated fairly. Finally, if sailors make realistic choices, their preferences should be met.

Trust in the Objectivity and Reliability of the Process. Users must feel that the process is fair, objective and consistent. Sailor-billet matches, billet availability lists and advice output by the process must be seen as consistent with policy, and uniform across the board. Sailors and placement officers should not feel that information is kept from them. The accuracy of the data it uses, the system up-time and the assurance that it will not lose any transactions will prove its reliability. The process must be transparent and any deviation from the norm should be controlled, minimized and explained.

High Proportion Of Matched Sailors And Billets. For the redesigned process to succeed, it must be able to automatically match a high proportion of the available sailors to the available billets. Every distributable sailor must be matched to a billet or training vacancy. However, there are constraints where a 100% match is not possible. The remaining sailors who are not automatically matched may have to be matched manually. With process controls, technology and leadership, the proportion of computer assigned matches can be very high. Manual or forced matches (where a sailor is matched to a billet that is not in his preference list) must be minimized.

High Quality of Matches. Apart from quantity (proportion), the quality of the matches must be high. For commands, a quality match is defined as being assigned a sailor who meets its requirements and ranks highly in its list of preferences. Likewise, sailors would consider a billet match as high quality if the billet features highly in their preference list and/or the billet fulfills their desired attributes for their next assignment. On the whole, the current process produces high quality matches from the command's viewpoint but low quality matches from the sailors' viewpoint i.e., we have highly command biased matches. The redesigned process must be able to concurrently meet the need for quality matches from both the sailors' and commands' perspective.

Stability of Matches. A stable match is defined as one where the match is "not blocked by any individual or any pair of agents" (Roth, 1990, p21). Suppose a match proposes to assign sailor A to billet 1 and sailor B to billet 2. However, if sailor A prefers

billet 2 to billet 1, and similarly if billet 2 prefers sailor A to sailor B, then both sailor A and billet 2 will block the proposed assignment. The match is considered unstable as both sailor A and billet 2 will seek to obstruct the match and seek a match with each other. In the case of the Navy's assignment process, stability is important as it eliminates the practice of sailors and commands from rejecting offers and seeking each other out through 'old boy' contacts. If there are too many unstable matches, many sailors and commands will have the incentive to seek their own means of negotiating matches other outside of the formal assignment process. Therefore, it is important that matches of sailors and billets be stable, even if commands or sailors do not get their first choices – sub optimality may exist.

Flexibility to Deal with Exceptions and Dynamic Changes. The process must also be flexible and robust enough to cope with the many exceptions and dynamic changes from the norm that arise when dealing with a large number of individuals and commands. For example, an important billet may abruptly be gapped. To reduce the cycle time, the billet should be included in the current requisition cycle once it is gapped, so that it will be considered in the current matching round. The dynamic nature of Navy personnel management and operational needs require that exceptions must be managed to make sure no sailor or billet 'falls in between the cracks'. Such cases must be managed fairly, consistently, and in a timely manner. An exceptions management process must be put in place. Also, as described in chapter 2, the technology available affords DSSs to be flexible enough to accept dynamic inputs in proposing solutions.

Maintain the Human Touch. The process must still maintain a considerable portion of human to human interaction to preserve its paternalistic feel, despite the fact that technology can completely replace the CCCs, detailers, and placement officers. As career management involves CCCs and detailers counseling sailors, the human interaction aspect remains crucial.

B. CONSTRAINTS OF THE NAVY THAT HINDER THE DIRECT USE OF AVAILABLE TECHNOLOGY (4 MANAGEMENT FRAMES).

Several constraints that exist in the Navy hinder the technology described in Chapter II. This section examines these constraints to understand how they might impact the redesign process. This in turn will impact how the technologies can be configured and integrated with a redesigned process to make quantum improvements to the distribution process. These constraints consist of organizational objectives and behavioral attributes that currently exist in the distribution process. In most design situations, only structural constraints are considered, leading to implementation friction and resistance by stakeholders who may have different considerations. To appreciate the entire scope of all these constraints, the process is examined through four management frames – structural, human resource, political/power, and symbolic/cultural. These four ‘lenses’ allow different dimensions of the process to be wholly appreciated in the context of how the redesign will be constrained.

1. Structural Constraints

Structural constraints that have to be considered include the following:

- Priority Billets.
- Tied Movers.
- Exceptional Family Member Program.
- Relatively fixed PRDs.
- All Sailors Must be Matched to a Billet.

<u>Priority Billets</u>. The Navy currently prioritizes its billets in order of importance. P1 billets are the most important billets and have to be manned at 100%. These are usually in key operational positions, like nuclear submarines, Special Forces, and commands participating in high visibility operations. P2 and P3 billets are of lesser importance and need not be manned at 100%. Two-sided matching algorithms that only consider the entire pool of distributable sailors and billet requisitions without considering

this prioritization may assign less than the 100% target for P1 billets. This is likely to happen if not enough sailors state P1 billets as their preference. A direct application of two-sided matching without consideration for this manning policy will lead to shortfalls in manning targets. Detailers may have to manually intervene, requesting sailors to volunteer, or as a last resort, ignore some sailors' preferences and assign them to these billets. However, if detailers have to force sailors into billets they did not choose, this may hamper confidence in the objectivity of this process. If two-sided matching is used, adjustments to the process need to account for this constraint. To fill priority billets, a 'carrot and stick' method can be used to get the required number of sailors into these positions. 'Carrots' or incentives can be given to sailors to volunteer for them. Examples include giving them higher priority for their future choice of assignments, and monetary benefits. Unmatched billets can also be carried over to the next cycle to go through one more round of matching. 'Sticks' or coercive measures include forcing sailors to include priority 1 and 2 billets in their list of preferences, matching higher priority billets first and/or forced matching of sailors into priority billets if there are still gapped billets.

Tied Movers. The policy of moving married couples who are both active Naval personnel to commands in the same geographic area constrains the direct application of two-sided matching and optimization algorithms to the assignment process. i.e. if a sailor gets assigned to San Diego, detailers will try to assign the sailor's spouse to San Diego within the same time frame. This policy promotes family life, and as a side benefit reduces PCS costs. A simple two-sided matching algorithm only considers individuals and matches them to individual billets and does not consider 'tied movers' like married couples. Screening technologies can take this constraint into consideration in producing commands' 'ranked-preference of sailors' lists. Screening will effectively filter out geographic areas that appear in one spouses' list of eligible commands but does not appear in the other spouses' list, thus reducing the number of commands for which each spouse if eligible. Scoring algorithms will also have to consider the combined score of both the sailors for the billets in which they are ranked, i.e. they must be considered as a

pair in all rankings and their rankings adjusted accordingly.[3] For example, Sailor Smith may be ranked number 1 by a command in San Diego and number 3 by another command in Hawaii. His spouse may be ranked number 9 in another command in San Diego and number 5 in another command in Hawaii. The Navy will achieve the best paired ranking if it assigns the couple to Hawaii as their average rank is 4 (3+5 / 2) compared to an average rank of 5 (1+9 / 2) if they were to be assigned to San Diego as a pair. As a pair, the scoring and ranking algorithms should rank them as a pair and reflect Hawaii as a higher ranked pair for both couples. As can be seen, this policy reduces the utility for the commands that have to give up their higher ranked sailor and settle for a lower ranked sailor. e.g. the San Diego command has to give up Sailor Smith (its first choice) and settle for a lower ranked sailor. This policy also reduces the choices of billets for the sailors. One spouse may also have to give up being assigned to a billet for which they are highly ranked. Therefore, such sailors should be given a choice as to whether they want to be considered tied movers.

<u>Exceptional Family Member Program</u>. The Exceptional Family Member Program (EFMP) is a mandatory program designed to identify Navy family members with long term health care or special education needs. The program coordinates with overseas screening authorities to confirm the availability of medical and educational support at overseas locations, identifies those who require assignment within major medical areas, and those who are eligible for homesteading under current Navy policy. This program limits the number of billet choices for sailors under the program. Simple two-sided matching does not take this into consideration.

<u>Relatively fixed PRDs</u>. Projected Rotation Dates (PRDs) are relatively fixed for Navy enlisted sailors, where sailors rotate to another billet every two to three years. In fact, sailors have to remain in a billet for at least two years before they are rotated. This allows them time to be sufficiently proficient in their jobs, to maintain personnel stability at the commands, to sustain the flow of personnel through the career path, and to reduce

[3] This solution only considers enlisted sailor pairs (assuming all enlisted sailors use the redesigned process) but not if one spouse is an officer (who are assigned with another process). Calculating paired scores across

PCS costs. For the sailors, this constraint also affords them stability in their personal lives. On the downside, a sailor who may not be suitable in an assignment will have to bear out the two years. This may affect performance to the command's detriment. Currently sailors found inadequate by the commands can be reassigned without constraint, the numbers are very few and usually reflect disciplinary or security issues. There are likely many more sailors who feel they are not suitable for the jobs for other reasons, but are not considered for early reassignment (e.g., personality-to-job mismatches, inability to fit with the rest of the work team, changes in family situations, etc). Given these pros and cons, the process redesign will have to reconsider the current constraint of a minimum time period a sailor has to spend in a billet before being considered for reassignment, and the process redesigned to account for this.

<u>All Sailors Must be Matched to a Billet</u>. Unlike a civilian employment job matching process, where it is permissible for some job seekers not to be matched, all sailors considered for rotation must be matched to a billet, be sent for training, or remain in their current billet. This is not a problem generally because the number of billets exceeds the number of sailors. However, in some ratings, MOS, NECs and paygrades, at some point in time, there may be an excess of sailors over the billets that accept these sailors. The process must be flexible enough to assign sailors to billets for which they may be under or over qualified. For under qualified sailors, they can be sent for qualification training. For over qualified sailors, they can possibly fill billets they are over qualified for, or be sent for training to acquire another MOS or NEC that allows them to be cross-deployed to another billet. The redesigned process must consider this constraint and assign all sailors to a billet or training stint. A knowledge based career counseling system must also be intelligent enough to recognize such situations and recommend the appropriate cross MOS training for these sailors.

2. Human Resource Constraints

The Human Resource frame alerts the process designer to human motivational

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two separate systems is not as straightforward as compared to the case where both are enlisted personnel.

effects that the process may have on the sailors. The issues that constrain the design are:

- Need for Human to Human Interaction
- Perceptions of Equity.

Need for Human to Human Interaction. As discussed earlier, human interaction in the assignment process is important to preserve the paternalistic culture. Through human interaction, qualitative information not normally captured by computer systems can be gained. Although technology can mimic the agents in the process to a large extent (detailers and CCCs), there is still need to rely on human interaction to communicate desires, constraints and advice. The application of technology to the process is constrained here to provide concise and timely information for the various users, and not to completely substitute human agents. However, the process can be streamlined so that sailors need not talk to both CCCs and Detailers. Ideally, they should only need to talk to one person who represents them in all the transactions so as to avoid confusion and wasted time and effort in contacting multiple agents. The CCC appears to be the best person to represent the sailors' only contact point to the process. Sailors have more ready face-to-face access to their CCCs, compared to their detailers whom they have to contact via e-mail or telephone. If CCCs serve as the single point of contact, CCCs must be equipped with tools and information to provide sailors guidance on the latest billets available and their progress in the detailing process. Here, an integrated KBS will be a useful tool for CCCs.

Perceptions of Equity. Equity theory involves an individual's perception of his ratio of outcomes to inputs. Such outcomes include pay, promotion, recognition, status and in this case, meeting the sailor's assignment preference. Inputs include contributions like effort, performance, skill, and quantity and quality of production. Individuals compare their own ratio with that of others to determine if equity exists i.e. they compare O^{self} / I^{self} vs O^{others} / I^{others} where 'I' is an individual's input, and 'O' are outcomes received by individuals. If there is a *perceived* inequity, individuals take steps to increase the outcomes (rewards) they receive or decrease their inputs (effort). It will be not uncommon for sailors to compare themselves to other sailors and they see if they get their

just rewards. Questions like "How did Sailor Jones get his choice of billet while I didn't get mine?" will be common. Sailors may even wrongly equate their current work performance with being rewarded with their choice assignment, when in actual fact, performance is only one of many variables that are considered. CCCs can clarify the situation but many sailors are passive about such issues and this unhappiness is commonly informally aired with their peers and families. The process has to consider that misguided comparisons like these will go on all the time, and this may undermine trust in the process objectivity and fail to motivate jaded sailors. The redesign must examine innovative ways to combat misperceptions. DSSs can produce personalized information packets that educate sailors and allow them to compare their case with a benchmark case. The process should also be transparent, and easily understood by all stakeholders. Here education plays a key role.

3. Political/Power Constraints

The political/power frame views the process through the ability of the actors to shape the outcomes of the distribution process through legitimate, coercive or persuasive means. In this case, the issues that will constrain the redesign are:

- Detailers' power to influence the assignments.
- EPMAC's Authority to approve and veto assignments.
- Experience of CCCs versus 'know all' KBS

<u>Detailers' Powers</u>. Detailers currently have the authority to assign sailors to billets based on what they think is the best fit that satisfies the assignment guidelines, although different detailers may have different heuristics in matching sailors to billets. They have the power to decide to which billet to assign a sailor, based on their own judgement, albeit a sometimes subjective one. With an automated two-sided matching process, the optimum matches are made objectively and consistently. To exploit this positive aspect of the two-sided matching model, the power of the detailers to decide on all matches may have to be pared down. Detailers may only be granted power to manually assign sailors

who are not matched by the two-sided matching model, or ad hoc assignments that have special requirements that may fall out of the model's scope. The power and responsibility of auditing the quality of the matches assigned automatically by the two-sided model and those done manually by the detailers, may have to fall on an independent third party like EPMAC. This would ensure that the redesigned process is as objective as possible without any possible subjective interference by detailers. This will promote a level playing field for all sailors and not depend on their level of access to their detailer.

EPMAC's Authority to Approve and Veto Assignments. EPMAC currently has the ultimate power to approve or veto all assignments. This quality control check ensures that the manning targets are met, that career path guidelines are followed and in general that all assignment policies are followed. But EPMAC currently has no way to check the optimality of the matches. Employing optimization technologies and two-sided matching models in the assignment process, EPMAC will have to audit the quality of the matches to ensure the process is functioning as planned. Effective summary reports will be required for EPMAC auditing. With the power to police the process, EPMAC will be the appropriate agency with the ultimate power to veto and approve the matches, recommend changes to the system's algorithms, and to finally issue the assignment orders.

Experience of CCCs versus 'know all' KBS. Experienced expert CCCs may challenge the ability of a career counseling KBS tool to adequately produce summary outputs to provide sailors sufficient and accurate career information. With sailors interacting directly with CCCs, it is important that sailors trust the CCC's expertise to provide them sound and accurate guidance. The CCC's 'expert power' must be strong enough to convince sailors of the right decisions. In turn, CCCs must trust the accuracy and reliability of the KBS to provide useful and up to date information. The KBS outputs must complement the CCC's expertise and not totally replace them. Each will serve mutually reinforcing roles. The KBS forte is to collate and summarize organization wide information. It will play the role of providing useful and up to date career guidance information based on the billets available, sailor attributes and preferences, and career path guidelines, etc. The CCCs' role is to take this valuable information and combine it

with specific qualitative sailors' circumstances to educate and persuade sailors through face-to-face interactions.

4. Symbolic/Cultural

Culture of 'Duty before Self'. The culture of putting the needs of the Navy before one's own needs runs deeply in the Navy, as it does in all military services. This ethic is a key component that distinguishes a career in the Navy from just being a mere job to one that connotes a higher calling and a vocation. The virtues of self-sacrifice, duty and obedience are important ideals that the Navy would like to preserve. Navy Leadership would be loathe to allow a culture where a job is a mere exchange of services rendered in return for compensation to creep into the Navy. If sailors are given too much leeway to choose or even reject assignments, this culture of 'Duty before Self' may be eroded. The challenge then, is to balance the need to maintain this ideal whilst concurrently looking after sailors' needs in their career aspiration, quality of life issues, and pay and benefits issues; balancing the ethic of 'Duty before Self' with sailors' needs has key implications to redesigning the distribution process.

The key factor to balance these seemingly dichotomous needs is the concept of 'Fairness.' Sailors will embrace the 'Duty before Self ' ethic more readily if they feel they are fairly treated. They have to feel fairly treated vis-a-vis their fellow sailors and military counterparts in the Army, Airforce and Marine Corps. Here, incentives in the distribution process will have to promote fairness. The objectivity and consistency of the process will also be key to promote fairness. Although sailors are allowed to choose their assignments, they recognize that ultimately the Navy's needs must still come first. This implies a command biased two-sided matching algorithm would be appropriate. To maintain the dictum of 'fairness,' sailors who had to forgo their choices to fulfil their Navy's requirements (e.g. back-to-back sea duties or deployments in undesirable locations), could be given priority in their next assignment. Restricting the choices of a sailor could also balance the sailors' and Navy's needs (e.g., sailors' choices could be restricted to billets for which that they are eligible and are ranked above the median or

some other cut off point).

C. CHAPTER SUMMARY

In this chapter, Critical Success Factors (CSFs) and Navy constraints that will shape technology and the redesigned process were discussed.

The CSFs identified were the need to :

- have smooth, timely and accurate information flows in the process,
- manage and meet sailors' expectations,
- ensure that users trust that the process is objective and reliable,
- have a high proportion of sailors and billets automatically matched by the process,
- have a high quality of matches where sailors' and commands' preferences are met concurrently,
- maintain flexibility to deal with exceptions and dynamic changes,
- maintain a human touch.

The constraints that would have to be considered in the redesign process were examined using the four management frames– structural, human resource, political/power, and symbolic/cultural.

Structural constraints include prioritizing billets given the shortage of sailors to fill all billets, and the issue of tied movers (assigning married couples in the Navy to the same locations). Another constraint is posed by sailors who have family members with special needs, falling under the Exceptional Family Member Program (EFMP), and can only be assigned to commands with services that support the program. Relatively fixed PRD and the need to assign all sailors to a billet or a training slot also pose process constraints.

Human Resource issues that need to be considered include the need to maintain

human to human interaction in the process, the need to streamline the number of parties sailors contact about career and assignment issues, and the need to manage the perceptions of equity among sailors.

Political and Power issues include the detailers' ability to decide the sailors' assignments. If an automated matching system were implemented, the detailers' power to decide assignments needs to be curtailed to those instances that require manual matching. The power to audit the process needs to fall to a third party – EPMAC to ensure parity, fairness and proper functioning of the process within policy boundaries. The 'expert power' of CCCs also needs to be reinforced and not diminished by implementing technology. A knowledge based career counseling system can reinforce the CCC's role to educate and persuade sailors on career choices.

The culture of the military, where sailors are expected to put 'duty before self,' must be maintained despite the ability for the process to give sailors more say in their assignments. The dictum of 'Fairness' in managing sailor careers must strike a sound balance between the Navy's needs and the sailors' welfare. Only then will sailors embrace the virtue of 'duty before self'. The redesigned process must be objective, fair and promote this virtue rather than erode it.

So far, this thesis has examined the shortcomings of the current distribution process and the opportunities that technology presents to the process redesign. The critical success factors have also been discussed, providing a 'must do' checklist for the process redesign. The Navy constraints discussed, define the boundaries that must be considered in the redesign process. With these issues in mind, this next chapter will propose a redesigned distribution process to satisfy the Critical Success Factors within the relevant Navy constraints.

IV. PROCESS REDESIGN AND DECISION SUPPORT SYSTEM SPECIFICATIONS

A. PROPOSED DESIGN - DESCRIPTION OF REDESIGNED PROCESS

1. Redesign Methodology

A baseline redesign methodology is used in this thesis where incremental changes are made to the current process with many of the current structures kept in place. It seeks to make important changes to the process while retaining some of the current institutions and activities. By altering some key processes, leveraging on the strengths of the current process and available technology, yields significant gains. With incremental changes, actors in the process are familiar with the other players and their key roles and need not re-orient themselves to radically new players and institutions. This also avoids costly and time-consuming radical reorganization of structures and roles if the process were to be completely replaced by a new one. Also, implementation will be a lot easier with the required institutions and staff already in place. It is important to get the process to run smoothly and quickly upon implementation to gain acceptance and credibility among the users; the ease of transition from the current to the new process has to be considered. The redesign challenge is to produce a new process that can generate quantum improvements in the outcomes while ensuring that implementation constraints are met. With this in mind, a pragmatic baseline approach will target critical components of the process for improvement with the right doses of technology and process innovation.

2. The Redesigned Process In Brief

The redesigned distribution process consists of five main steps. In brief, the first step is the allocation sub process, which remains largely unchanged from the current process. Step two is the screening and scoring stage. Sailors are screened for eligibility for billets based on their characteristics. These characteristics are matched to the job requirements and sailors who meet the job requirements are short-listed. The short-listed

sailors are then scored based on how well they fit the commands' requirements. In step three, sailors meet with their command career counselors to receive career guidance and then 'apply' to billets for which they are eligible, with each sailor stating his billet preferences in ranked order. Step four then uses two-sided matching algorithms to assign sailors to billets based on the sailors' list of preferences and the commands' list of preferences. In step five, exceptions are managed, and matched sailors and billets are audited for fit and adherence to policies, before the orders are written.

The process will leverage on technology encapsulated in a proposed integrated decision support system called **NERISSA**[4]**; short for Navy Enlisted Resource Integrated System for Smart Assignments**. Modules of NERISSA will be discussed in the process description and in section A, part ii of this chapter.

Recall from Chapter III that there are five main structural constraints on the matching system: 1) Prioritization of billets, 2) Tied movers 3) Sailors on the Exceptional Family Member Program 4) Relatively fixed PRDs, and 5) All sailors must be assigned to a billet. The process redesign takes these constraints into account.

3. Step 1 : Allocation

Process. Allocation, the first phase of the distribution process, remains largely unchanged from the current process and is detailed in Figure3.

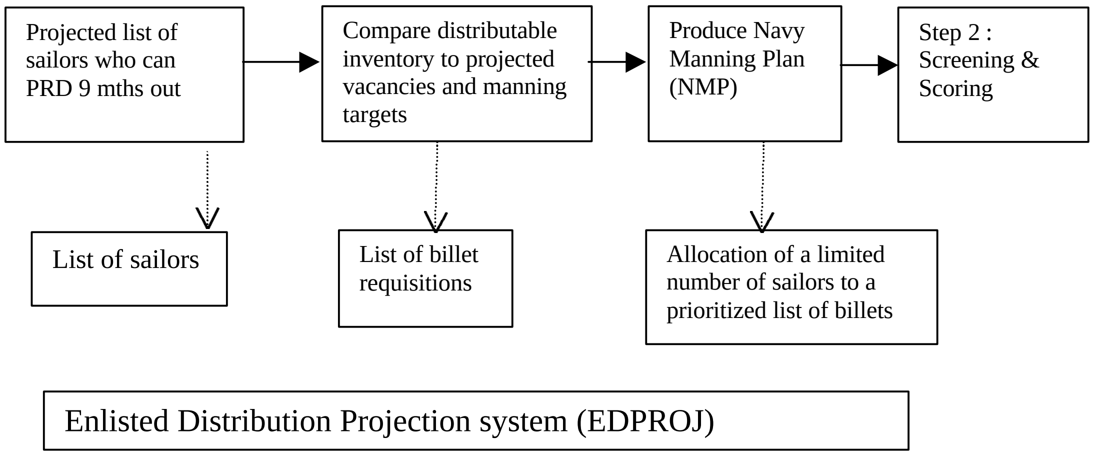

Figure 3 – Step 1 : Allocation Process

Firstly, The distributable inventory and billet requirements are projected nine months out. Secondly, distributable inventory is compared to the projected vacancies and manning targets determined for each priority level: e.g., P1 billets –100%, P2 Billets 90%, P3 Billets –75%. This part of the process ensures that the CNO's and commands' manning priorities are reflected, based on operational tempo and strategic importance. Thirdly, the Navy Manning Plan (NMP) is produced. It contains the allocation of a limited number of sailors to a prioritized list of billets to guide detailing and placement - how many sailors will each priority level receive. For example, the NMP may indicate that to bring P1 Corpsmen billets to 100% manning, 50 Corpsmen must be assigned, and to bring P2 Corpsmen billets to 90%, 40 Corpsmen must be assigned. The NMP will guide the assignment process to ensure the appropriate numbers of sailors in each rating are assigned to the intended priority levels. This allocation of sailors is completed for every enlisted rating and for every paygrade.

The following data are generated from the allocation process:

[4] Nerissa : from the Greek form Nerisis, meaning 'Sea Sprite' or 'from the Sea.'

- Sailors – Details of sailors who are distributable 9 months out (rank ,name, Rating, MOS, etc.)
- Billets – Details of billets that require sailors 9 months out (Billet number, rating requirement, priority etc.)
- Allocation – What are the manning targets for each priority level in each rating? How many of each type of sailor is each priority level of billet to receive?

EDPROJ. Currently, the entire process is carried out by the Enlisted Distribution Projection system (EDPROJ), which combines sailor data from EMF, and billet data from TFMMS. The data generated is electronically downloaded into the Enlisted Personnel Requisition System (EPRES) that generates a requisition for personnel through the Requisition Posting Module (RPM) in the Enlisted Assignment Information System (EAIS) that is used by Detailers. The features and functions of EDPROJ can be integrated into NERISSA en-bloc as a module that performs the projection and allocation tasks. Instead of EAIS, The projected allocation numbers are then downloaded into NERISSA's shortlisting and scoring, and matching modules, so that NERISSA's matching models and optimization in NERISSA have target numbers to work towards.

4. Step 2: Screening and Scoring

The next step of the distribution process screens sailors to determine billets for which they are eligible. Eligible sailors are then scored based on their attributes viz. billets requirements. This process is summarized in Figure 4 on the next page:

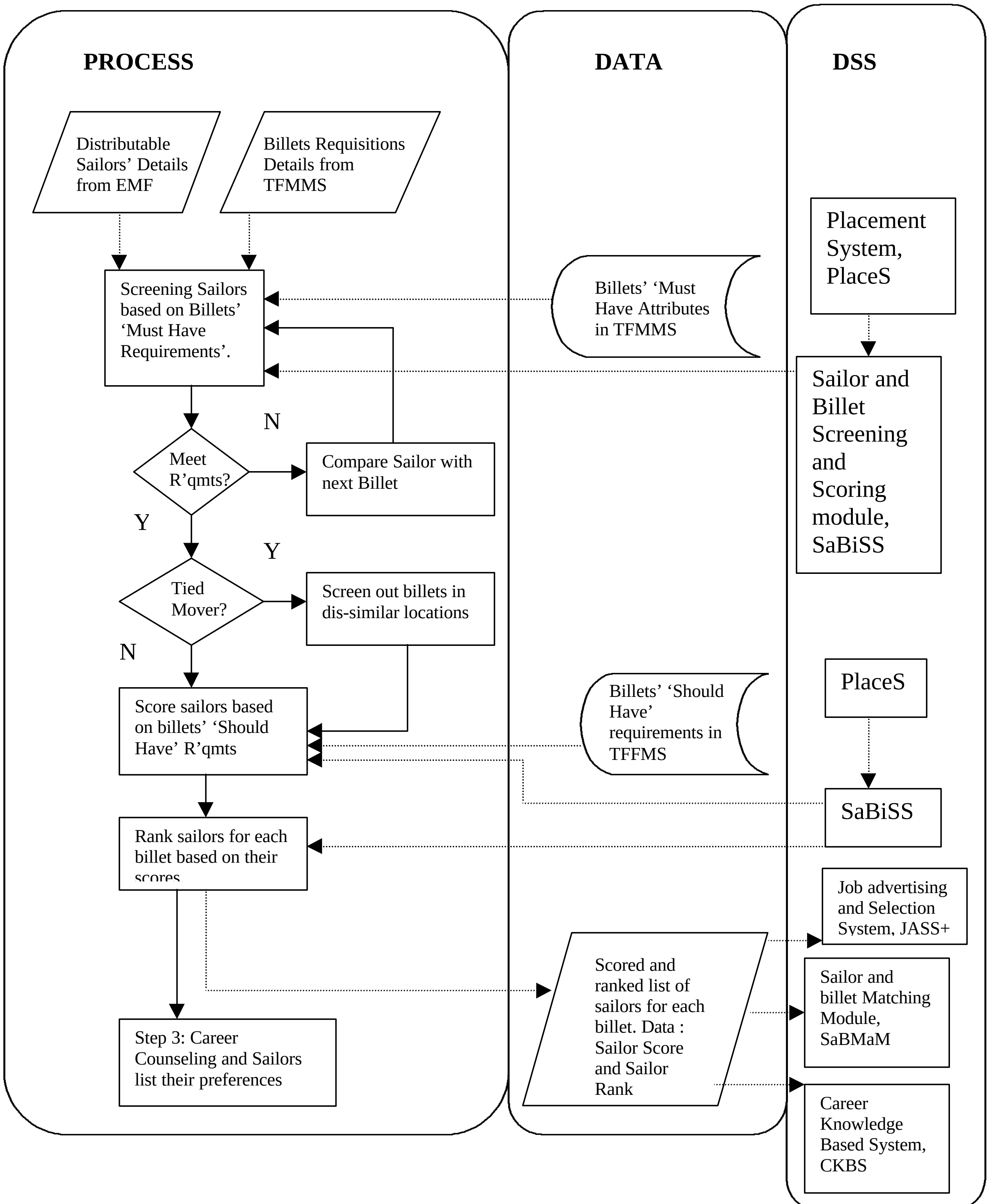

Figure 4 – Step 2: Sailor Screening and Scoring Process

<u>'Must Have' and 'Should Have' Sailor Attributes</u>. When the NMP is sent to NERISSA, EPMAC will run the **Sailor and Billet Screening and Scoring (SaBiSS)** module within NERISSA for all ratings. SaBiSS will short-list distributable sailors who are eligible for the billets projected to be vacant. Each billet will have a list of characteristics that it requires in a sailor. These characteristics can be divided into **'Must Have'** and **'Should Have'** groups. In effect, SaBiSS replaces part of the job of the career counselor, detailer, and EPMAC, which is to screen sailors for eligibility and rank them according to command's preference. For details on the attributes that impact the commands' and sailors' choices for each other, refer to "Characterizing Sailor and Command Enlisted Placement and Assignment Preferences." by Butler and Molina (2002)

'Must Have' factors are characteristics that the sailor must possess before being considered for the job, and can include the following:

- Correct Rating, MOS and NEC (e.g. a Corpsman cannot be considered for a Nuclear Technician's job).
- Projected rotation date must fall within the window required by the commands.
- Correct gender where applicable (submarines still do not take female sailors).

'Should Have' factors are attributes sailors should but need not necessarily have to be assigned the job. However, having them will make them a better fit to the billet. These factors might include the following:

- Right rank or pay grade. Most commands can accept a sailor a pay grade above or below the required pay grade.
- A current location that is not too far from the billet location to minimize PCS cost.

- Previous experience required on the same type of ship or department.
- Correct sea to shore rotation cycle. A sailor who is currently in a shore deployment should be rotated to a sea assignment.
- PRD. Sailor can PRD to new billet at the 'right time' where billet gapped time is minimized.
- Participation in the Exceptional Family Member Program EFMP.
- Incentive attribute for bonus score for volunteering for priority billets.

Representing Command's Needs Through the Placement Sub-System, PlaceS. The **Placement Sub-System (PlaceS)** within NERISSA allows placement officers to represent their commands' qualitative needs. The default requirements of billet requisitions are downloaded from TFMMS to PlaceS. In PlaceS, placement officers can see up-to-date information of all their commands' billets that are up for requisitions, and their details like billet name, job description and requirements, manning priority, and sailor 'Must Have' and 'Should Have' characteristics. At initialization, a set of default 'Must Have' and 'Should Have' requirements will be configured for every enlisted billet in the Navy. Subsequently, placement officers can use PlaceS to toggle on/off each attribute and adjust the weights of the 'Should Have' attributes in order of importance. They can choose to put more weight on important attributes, less or no weight on less important or unimportant attributes, or use the PlaceS default for equal weighting on all 'Should Have' sailor attributes. This, in effect, allows placement officers to represent their commands' needs to the distribution process if there are any exceptions from the initial default weights and scores. After sailors are scored, placement officers can then use PlaceS to view the ranked list of sailors for each billet in their command.

Screening and Scoring Sailors Using SaBiSS. For each billet requisition, SaBiSS will first screen out sailors who are not eligible based on the 'Must Have' factors. The sailors who are eligible will then be scored and ranked based on their 'Should Have' factors. Each 'Should Have' factor will have a weight and a scoring range. For example, E5s who meet the E5 paygrade requirement for a Sonar Specialist on a submarine will be given 10 points. If 'pay grade' has a weight of 5%, the net 'pay grade' score for being in

the desired pay grade is 0.5. For an E4, the score could be 7, or a net ‘paygrade score’ of 0.35. The total net scores of all the ‘Should Have’ requirements are added up and the short-listed sailors ranked in descending order of their total scores. The sailor with the highest total score represents the sailor that best fits the job based on the stated job requirements and that sailor is ranked as the billet’s first choice. Those with lower scores represent sailors who meet the billet’s ‘Must Have’ requirements, but fall short in varying degrees on the ‘Should Have’ requirements. All sailors are similarly put through this scoring system and rank ordered for every billet for which they are eligible. This ranked short-list represents all the sailors who meet the minimum job requirements and are rank ordered by the command preferences for the list of eligible sailors.

Scoring Metrics Concepts. After identifying ‘Should Have’ variables, values (metrics) are defined for each attribute. The method of assigning scoring metrics should follow these principles:

- **Meet Requirements**. Sailor attributes that meet ‘Should Have’ requirements will score a base score of 10 for that requirement. This decimal metric serves as a convenient basis to vary scores for sailor attributes that exceed or fall short of requirements.

- **Shortfall in Requirements**. As a shortfall in an attribute increases, the more the score will decrease for that attribute, representing a growing disdain by commands for such sailors or a growing decrease in commands’ satisfaction/utility. Generally, scores will decrease on an increasing scale. For example, there may be a requirement for a sailor to have at four years of previous experience on a particular class of ship. A sailor with four years of such experience will score a 10. A sailor who has three years experience will score say an 8 (a decrease of 2) and a sailor with two years, a 4 (a further decrease of 4).

- **Exceed Requirements**. If sailors’ attributes exceed the commands’

preferences, scores will increase but on a decreasing scale, representing a reducing marginal increase in satisfaction. Using the example of shipboard experience above, a sailor who has five years experience may score a 13 (an increase of 3) and a sailor with six years, 14 (a smaller increase of 1).

- **Policy Constraints and 'Cut-Offs'**. Due to manning control policies, some attributes will have a negative score if they exceed the commands' needs or fall too far short of requirements. e.g. an E5 exceeds a E4 billet requirements, and manning policy strongly discourages 'over-manning' a billet. Sailors who exceed or fall short of these policy requirements by too much will be disqualified and screened out at the screening phase; e.g, E8s or E1s will be screened out for an E5 billet.

- **Commands' Needs vs. Navy Policy Needs.** Commands' needs refer to sailor attributes that impact the commands directly and largely involve the sailors' ability to perform the job reflected in the sailors' performance records and training. Navy policy needs refer to sailor attributes that impact navy wide policies and largely involve costs and quality of life issues, like PCS costs and sea-shore rotation cycles. Placement Officers can use PlaceS to make adjustments to the scoring metrics only for command needs attributes and change the weights and the scoring scale to reflect the commands' needs. EPMAC should be the authority to make changes to the scoring matrix for Navy policy needs.

- **Bonus Scores.** Bonus scores are the total points awarded to certain sailors with the aim of boosting their overall score so as to set them apart from other sailors with otherwise similar attributes. Bonus points are awarded as incentives for sailors who previously volunteered for priority billets to encourage sailors to choose priority billets. Sailors on the Exceptional Family Member Program (EFMP) are also given bonus points to make up for the shorter list of billets for which these sailors are eligible.

- **Weights**. Each attribute has a weight that represents its level of contribution and importance to the command. The weighting system also forces commands to face a trade-off situation where they have to specify which attribute is more important to them. It is proposed that placement officers use the standardized weights in table 2 below:

Table 2 – Sailor Scoring Scale

WEIGHT	5	4	3	2	1	0
MEANING	Most Important	Very Important	Average Important	Moderately Important	A Little Important	Not Important

- **Total Sailor's Score = Total Command Needs Score + Total Navy Policy Needs Score + Bonus Score.** The total maximum score of a sailor (or billet) is moderated to 100, where '100' represents a sailor who, on the whole, meets all the requirements. '100' is a number easily understood by all users, and as a base will make comparisons easier. Note that sailors can exceed a score of 100 if they exceed requirements. Regardless, a score of 100 serves as convenient base for comparison. Command needs scores are scaled to a score of 50 and Navy policy needs scores are also moderated to a score of 50. Both are then added to give the total sailor attribute score. Algebraically,

Total Sailor Score, $S^T = (\Sigma(S_i^c * W_i^c) / \Sigma(10 * W_i^c)) * 50 + (\Sigma(S_j^p * W_j^p) / \Sigma(10 * W_j^p))*50 + S^B$

Where : S_i^c is the sailor's score for command needs attribute i

W_i^c is the weight given to command needs attribute i

S_j^p is the sailor's score for policy needs attribute j

W_j^p is the weight given to policy needs attribute j

S^B is the sailor's bonus scores

An example of the sailor scoring metrics for a billet that encompass the above principles is detailed in Table 3 below:

Table 3 –Scoring Metrics for 'Should Have' Sailor Attributes

Attribute/Score	Rq'mt	Weight	Meet needs	+1	+2	-1	-2	Remarks
				Increments				
Commands' Requirements								
Pay Grade	E5	5	10	8	Screen out	8	Screen out	Screen out sailors who +/- required paygrade by 2 steps
Previous experience	2 yrs	2	10	12	13	8	5	
Promotability	Promote	3	10	12	13	8	5	
PRD	06/02	4	10	11	11	8	5	
Etc…								
Navy Policy Requirements								
Minimum PCS	Pacific	4	10	NA	NA	8	5	Increment= # of changes in time zones
Sea –Shore Cycle	Sea	5	10	0	0	0	0	Score = 0 if sailor's next rotation is a shore duty
etc.								
Bonus Scores								
EFMP		5	10	0	0	0	0	Score = 0 if sailor does not have the attribute
Incentive Bonus Score		5	10	0	0	0	0	

Although the economics of these metrics have not been tested, these concepts for constructing sailor scoring metrics are robust enough for a more detailed scoring table to be constructed and tested. It will be an interesting topic for further research.

Bonus Points in Scoring - Incentives for Volunteering for High Priority or Hard-to-Fill Billets. To encourage sailors to volunteer for high priority billets (P1 billets) or for

billets that are traditionally undesirable (because of bad location, dangerous nature of the job, etc.), a bonus point system is used. The effect of these bonus points is to raise the scores of sailors who volunteered for such billets in their previous assignments. A sailor is awarded these points on top of the points he gets from being scored in the 'should have' attributes. Having a higher score would mean being ranked higher in general for all billets compared to a similar sailor who did not volunteer previously. This will give these sailors a better chance of being matched to their preferences. Sailors are considered to have 'volunteered' for priority 1 and these hard-to-fill billets if they listed them in their preference list and are eventually assigned to such a billet. They will be awarded bonus points in their next rotation. Sailors who were assigned to these priority or hard-to-fill billets but did not list them in their preference lists, are not considered as volunteers and will not be awarded bonus points. This incentive system will encourage sailors to volunteer for more of such billets by stating more of these billets in their preference list.

Screening and Scoring of Tied Movers. The policy of moving married couples who are both active Navy personnel to commands in the same geographic area requires the process to screen and score these tied movers together.

- First each sailor is screened for billets for which he/she is eligible. Next, tied movers are screened out for locations with billets for which either party is not eligible. For example, if sailor A is eligible for a billet in Hawaii, but his spouse, sailor B, is not, then both sailors become ineligible for Hawaii billets. When tied mover sailors view the billets for which they are eligible, they will also be presented the list of billets that were excluded because their spouses were ineligible for them. This allows them to see the 'cost' of being in the tied movers program, with the 'cost' being a shorter list of billets they are eligible for. As this process inevitably penalizes tied movers by constraining the number of billets and locations for which they are eligible, for each rotation, tied movers sailors will be given a choice to participate in this program or not.

- The next step is to score sailors who choose to be in the program. The

scoring system follows that of the other sailors. The sailors are then ranked only for billets in locations for which both they and their spouse are eligible.

Screening of Sailors on Exceptional Family Member Program (EFMP). EFMP sailors need to be prescreened and only be ranked by those commands that support EFMP. As these sailors have a reduced list of billets for which they are eligible, they will likely be penalized by having fewer billets that rank them well (as some billets do not support EFMP) and thus have fewer choices available. The process must be corrected to normalize EFMP sailors so as not to penalize them. This is done by including EFMP as a bonus scoring attribute that would be awarded to EFMP sailors. In effect, EFMP sailors will rank higher for a billet than non-EFMP sailors, all else equal, giving them priority of assignment.

Scheduling Sailors for Qualification Training. It must be noted that not all sailors immediately have the correct training to fill some billets. Sailors are often projected to fill billets for which they are not yet eligible, provided that they are scheduled to attend training en route. Therefore, the SaBiSS must be 'smart' enough to identify these sailors, recommend them to rotate to a training course before their next billet, and include them in the short-list. SaBiSS should not filter out such sailors. Therefore, heuristics must be captured in the models within SaBiSS to recognize such patterns of sailor who can become eligible. Components in such a heuristic could include time in current job, previous billets held, relevance of experience in previous billets to future jobs, career management and progression policies and the availability and scheduling of courses. This information will then be included in recommendations compiled by the Career Knowledge Based System (CKBS) module of NERISSA.

Electronic Transfer of Scores and Rankings to other NERISSA modules. After screening, scoring, and ranking sailors, the output is electronically transferred to the Job Advertising and Selection System, JASS+ module, and the Sailor and Billet Matching Module, SaBMaM, of NERISSA.

Summary. In summary, step 2 can be described as:

- **Inputs**: Navy Manning Plan containing manning targets, details of sailors (from Enlisted Master File), weighted requirements of billets (from TFMMS and PlaceS to include each billet's "Must Have and 'Should Have' requirements).
- **Process**: Use of a Sailor and Billet Screening and Scoring module (SaBiSS) to screen sailors according to job 'Must Have' requirements and rank the short-listed sailors according to how well they meet 'Should Have' job requirements.
- **IS / DSS Introduced**: Placement Sub-System module (PlaceS) and Sailor and Billet Screening and Scoring module (SaBiSS)
- **Outputs**: Billets' (Commands') ranked preference of eligible Sailors. This is electronically transferred to JASS+ module (a new version of JASS with more features) and the matching module, SaBMaM, in NERISSA.

5. Step 3 : Career Counseling and Sailors List Their Preferences

Before sailors can apply for billets and list their preference, they will need to receive career counseling. The career counseling and preference listing process is summarized in Figure 5 on the next page.

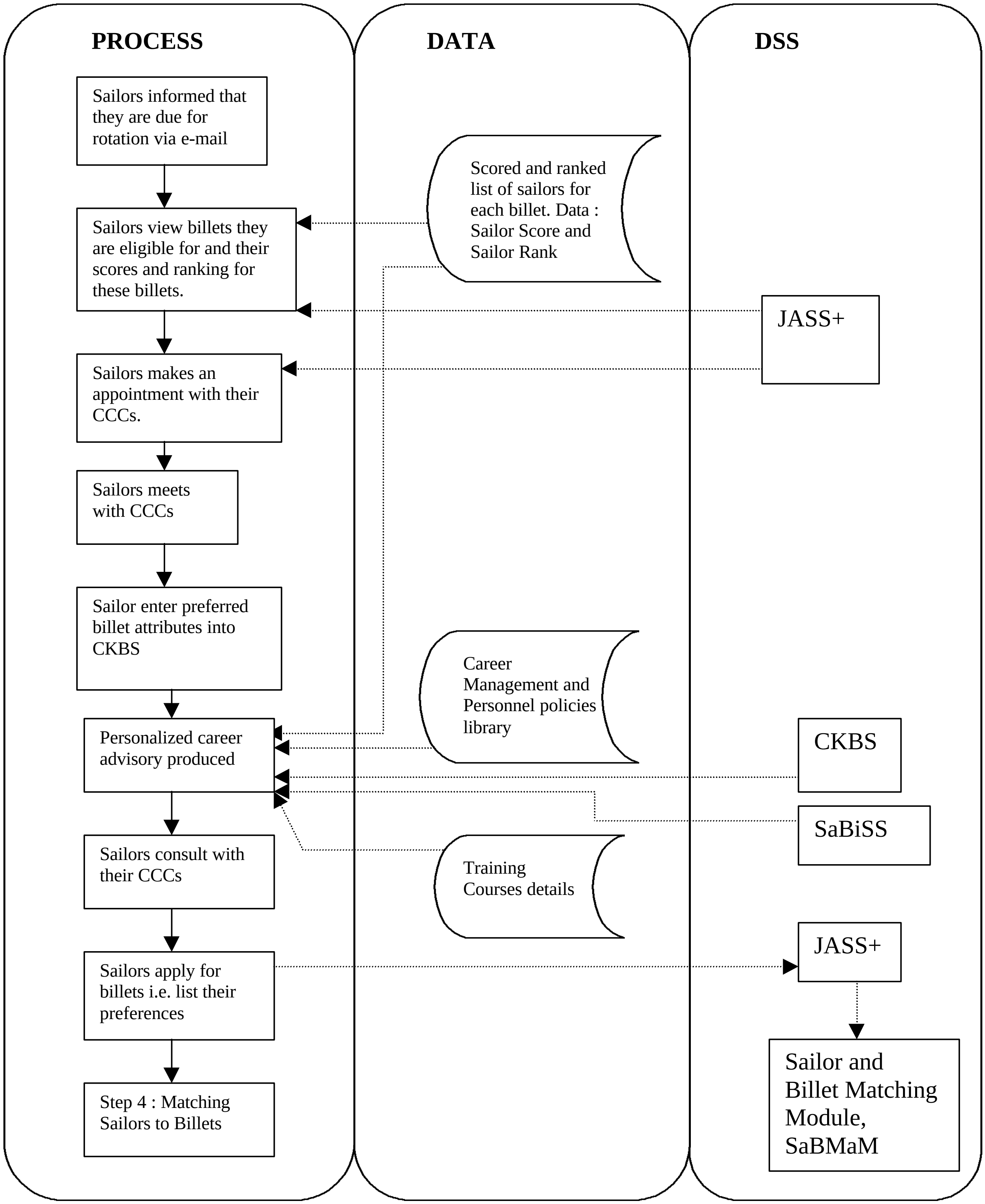

Figure5 – Step 3: Career Counseling and Sailor Preference Listing Process

Career Counseling and Preference Listing Process. First, sailors are informed that they are up for rotation. This can be done directly via e-mail to the sailors or via the CCCs (for sailors who do not have an e-mail account). Sailors also receive a 'what-to-do-next' information package via their e-mail to educate them on the process. This education process is important, especially in the infant years after implementing the redesigned process. Sailors then go to a new online system, called JASS+, to view the billets for which they are eligible, and how they rank for each billet. Thus, sailors will know the job to which they stand the best chance of being assigned. In a revamped version of JASS, called JASS+, they can retrieve all the information they need to make an informed decision. Sailors can then use this information to think things over or discuss it with their families before meeting with their CCCs. This will make the discussion with CCCs more productive. Next, sailors schedule an appointment to meet with their CCC. During the counseling session, CCCs will perform the following activities:

- Review the sailors' details including their training, experience, expected PRD dates and personal details. Update personnel records if necessary.[5]
- Review the billets for which the sailors are eligible and their ranking for each billet.
- Discuss the sailors' preferences for a set of billet attributes (e.g. location, sea/shore etc.) using the Career Knowledge Based System (CKBS).
- Discuss the sailors' personal and family needs
- Produce a personalized career management briefing sheet using the (CKBS), which takes into account career path needs, training possibilities, billet requirements, sailor preferences and manning policies.
- Discuss career path issues.
- Discuss training possibilities.
- Advise sailors on how to best compromise between their ideal choices and

[5] This step allows personal details of sailors to be checked and updated as it may impact the assignment process. CCCs will inform the personnel administration departments of their commands of any such updates.

realistic chances for being assigned to jobs based on their scores and ranking.

- Certify on JASS+ that they have counseled a sailor and that the sailor is now allowed to state preferences. This forces sailors to receive career guidance before making their choices. Sailors can state their preferences during discussions with their CCCs or do so on their own after that. This process symbolically places the onus on the sailors to be ultimately responsible for their choices.

After being counseled, sailors will have to make their choices by ranking their billet preferences. Ultimately, the sailors will rank their job preferences based on all the available information of how the billets rank them, their desired job attributes, their ranking of the jobs for which they are eligible, and their desired career moves. Sailors will then state their preferences using JASS+. Each sailor will have to list at least 12 billets and up to a maximum of 20 billets.[6]

CCCs serve as the sailors' only point of contact in the entire redesigned distribution process. In order to answer to sailors' queries, CCCs need to be equipped with all the relevant information This streamlines the process and provides a convenient and consistent link between the Navy and sailors, giving the process a human face – the CCC. Sailors no longer need to call different 'faceless' people during the process. The CCC, as the Navy key representative, also promotes the Navy's paternalistic image through this personalized process.

<u>Including Priority Billets in Preference Lists</u>. Sailors must include at least 5 priority 1, and 3 priority 2 billets in their preference list. CCCs must encourage sailors to list more priority 1 billets by explaining the incentive programs in place - the 'volunteer for priority billets' bonus points system and any monetary incentives. The more priority 1 billets they list, the higher their chances for being assigned to one. This will also increase the chances that priority 1 billets are filled to 100% as required by manning policy.

Listing of Preferences by Tied Movers. Tied mover sailors also list their billet preferences. However, they must make billet choices that are in the same locations as one another. For example, if sailor A ranks as his first choice a billet in Hawaii, his spouse, sailor B must also rank as her first choice a billet in Hawaii, and vice versa. They do this for all their ranked choices. To do this, they need to consider billets' rankings of them as a pair. This paired ranking of preference increases the chances of them initially being matched to the same location by the two-sided algorithm. Also, this process follows logically from the policy that paired movers choose to move together to the same location. It would not make sense from a practical or symbolic standpoint that tied movers rank their choices without regard for their partner's choices.

JASS+. JASS+ is a 'souped up' version of the current JASS that will play a key role as the 'front desk' of NERISSA where sailors, CCCs and detailers perform transactions. The current JASS has two key features: It advertises all billets open for 'application' in the current cycle and allows sailors to apply for billets via their CCCs. It functions largely as an electronic notice board with an electronic 'sign up' sheet for job applications and does not have any 'smart' features. JASS+ has more advanced features than JASS that sailors, CCCs, placement officers, and detailers can access. The features of JASS+ are listed as follows:

- **Sailors View - Only Screen**. Like the current version of JASS, sailors can view the billets available. However, unlike JASS where sailors see all available billets without any information on their eligibility, with JASS+, sailors can view billets categorized into those for which they are eligible and those for which they are not eligible. Beside each ineligible billet, JASS+ will also detail the reasons why the sailors are not eligible. By seeing all the billets requisitions, sailors can be assured that there are no 'hidden billets.' Tied movers can also see the billets from which they are screened out because their

[6] The ideal length of the sailors' preference lists should be studied in further detail. However, in Ng and Soh's thesis (2001), preliminary studies showed that for a sample of 45 sailors and 60 billets, a sailor's

spouses are not eligible for them. Sailors can also view their scores, their rank in each of these billets and their manning priority level.

- **Job Description Query**. Sailors can also retrieve job descriptions for billets they may be interested in. Job descriptions include roles and responsibilities for the job, skill and training requirements, base location, and manning priority level.
- **Sorting function**. Using the sorting function, users can sort each sailor's eligible billets by score and ranking, manning priority, location, command, and ship/shore. Detailers and CCCs can also sort sailors by score and rank, rating/MOS/NEC, command and location. The default sorting is by ranking order and priority level, and lists only the top 25 billets for which each sailor is eligible. This allows the information to be easily digested.
- **Appointment Scheduling**. An appointment scheduling program that allows sailors to schedule an appointment with their CCC negates the need for phone calls. It will also alert CCCs of sailors who have yet to make an appointment after 1 week of being informed of their PRD, perhaps because the sailors did not get the message. CCCs then contact sailors to schedule an appointment.
- **Summary Print Out**. After viewing their details online, sailors can print out a summary sheet of information containing their personal details, scores and ranking among billets for which they eligible, expected PRD dates, and scheduled appointment time with their CCC. Importantly, it also lists the factors they should consider when they are choosing billets, and a brief describing the screening/scoring and matching process. With this information, sailors can take time to make educated decisions before discussing their career moves with their CCC and submitting their billet preferences.
- **Billet Application Module**. After discussions with their CCC, sailors state their preferences in JASS+'s billet application module. Unlike the current JASS where only CCCs have access to this feature, JASS+ allows sailors to enter their own preferences and to change their preferences anytime before the

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preference list length of 12 will see more than 90% of the sailors matched to a billet.

sailor-to-billet matching run begins. However, before sailors can access this module, CCCs have to certify that they have counseled the sailor. After entering their preferences, sailors can print out a copy for their reference.

- **Progress Tracking**. Users can use the progress tracking screen to observe how their application is progressing in the distribution process. Examples include: “Your application has been submitted and will be processed in 7 days time.” and “Your application is currently being processed and a suitable billet will be assigned to you in 3 days time.” Sailors can access this feature to view their own progress. Likewise, CCCs and Detailers can access this feature for all sailors under their charge.
- **Help Screen**. A help page is included to educate sailors on how they are scored, and the factors involved. It also provides help on how to use the system’s features.
- **Natural Language**. The system will produce documents that use common natural English language to detail information in an easily understood and friendly format, vice the common military styled documents that contain excessive abbreviations, codes and sentences that resemble coded reports.
- **Security Features**. JASS+ provides individual password protected security features that will require users to log-in. Access limitations based on user identification will distinguish between sailors, CCCs and detailers and their access rights.
- **Rides on NMCI**. As a module of NERISSA, JASS+ resides on the NMCI network and can be accessed by all the global users of NMCI.

Career Knowledge Based System (CKBS). With this process, CCCs will not have to worry about sailors’ eligibility for a billet, as sailors can only apply for billets for which they are already screened. CCCs can concentrate on advising sailors regarding their career path rather than merely their next assignment. To assist, the career counselor can access a **Career Knowledge Based System (CKBS)** that will have knowledge and information to manage the career of all the different sailors’ vocations. The CCCs will have the latest information at their fingertips and they can access a broad range of

information they can use to accurately advise sailors. The CKBS also collates a broad range of information, including sailors' details, billets information, career management, and personnel and manning policies, into a concise advisory. The features of the CKBS are as follows:

- **Scoring Billets based on Sailors' Preferences**. To assist sailors in deciding which billets they prefer based on a set of attributes, CCCs can use this feature in the CKBS. The scoring and ranking process works very much the way billets score sailors. Sailors input their preferences over a set of billet attributes into this feature of the CKBS. The CKBS then takes these preferential attributes, electronically forwards them to SaBiSS which matches them to billet characteristics pre-entered in TFFMS. The scoring system and concepts are the same as that for scoring sailors described earlier. The SaBiSS module of NERISSA performs the scoring operations and forwards the results to the CKBS for electronic retrieval and compilation into an advisory. Only billets for which sailors are eligible are considered and scored. In effect, the outcome will be a ranked preference of billets for which sailors are eligible, based on the combined contribution of different billet attributes that a sailor values. With this list, sailors can then see clearly which job they prefer, given the jobs for which they are eligible and the attributes that they value. In effect, this tool will help the sailors to objectively rank billet choices. The attributes that are important in determining which billets are desired by sailors are (Butler and Molina, 2002):

  - Job Attributes – Ship/Shore billet, contribution to advancement, work Team/Work alone, hands on work, etc.
  - Location Attributes – Cost of living, availability and cost of housing, easy transition to civilian life, seasons/ climate changes, etc
  - Family Life Attributes – Co-location with military spouse, can be accompanied by spouse, ease of spouse finding a job, schools for children, availability of activities for families, etc.

- Incentive Attributes – monetary bonus, given priority for next assignment.
- Training and Education Attributes – choice of community colleges/university, able to learn a new specialty, etc.

- **Career Management Advisory**. The CKBS module produces a career management advisory sheet that details career management issues which CCCs can use to advise sailors. Such an advisory will contain the following information:
  - Sailor's Curricula vitae.
  - Typical career path for the sailor's rating.
  - Training opportunities, date of course commencement and graduation, location, and accreditation.
  - Sailors' ranked preferences of billets for which they are eligible, based on their preferences over the billets' attributes.
  - A recommended course of action for the sailor.
- **Online Personnel Resource Library**. An online library containing the latest personnel management policies, career management directives, billet descriptions, a phonebook of detailers, placement officers, and the latest in personnel news and trends will allow CCCs to access relevant policy information easily. CCCs can also use this resource to bring themselves up to date with the latest trends and policies. An 'updates alert' feature will notify users of any key updates to the library at every log-in.
- **Search Features**. Search features allow users to search the online personnel resource library for specific topics. It will also allow CCCs to search all the enlisted billets' details and sort them by location, expected time window where they will require a new sailor, and Rating/MOS/NEC requirements. With this tool, CCCs can answer queries by sailors about specific billets in which they may be interested but may not be up for requisition in the current cycle or billets for which the sailor may not be eligible.
- **Security and Networking**. These are similar to those described for JASS+.

Summary of Step 3. In short, step 3 of the redesigned distribution process contains the following elements:

- **Input** : Ranked commands' preferences of sailors (from SaBiSS). Sailors' preferences over billets' attributes are entered into the CKBS. Billet information and sailor information is pulled from TFMMS and EMF, respectively.
- **Process** : The sailors' preferences and the billets' attributes are compared, screened and scored with SaBiSS. Information from libraries, EMF, TFMMs, sailors' and billets' scores are compiled into a personalized sailor career advisory sheet. After meeting with their CCCs, Sailors enter their ranked list of billets into JASS+.
- **Output** : A sailor career advisory sheet containing sailors' information, billets available, scores and ranks for sailors, career path information, and advice on which billet to apply for. Sailors' preferences are listed in JASS+ and ported over to the matching system.
- **IS/DSS Introduced** : An enhanced Job Advertising system (JASS+) and a Career Knowledge Based system (CKBS) are include in step 3.

6. Step 4 : Two-Sided Matching of Sailors to Billets

Sailor-Billet Matching Module (SaBMaM). The sailors' preferences in JASS+ and the commands' ranked preferences of sailors from SaBiSS will then be ported into the matching system in NERISSA. The **Sailor-Billet Matching Module (SaBMaM),** NERISSA's matching module**,** uses a two-sided matching algorithm to match sailors to billets. Given the higher priority to fill the Navy's requirements over fulfilling sailors' preferences, SaBMaM will match sailors to jobs using a two-sided matching algorithm with a command bias. However, as the process encourages sailors to make educated choices which consider how commands' rank them, it is likely the results from a command-biased match will not differ very significantly from a sailor-biased match. Other methods of matching sailors to billets are considered in this paper, but the two-sided algorithm is chosen over them because two-sided matching promotes stable

matches. Other methods of matching include optimization algorithms to maximize commands' utility (scores of sailors), sailors' utility, and/or the sum of commands' and sailors' utility. These options are discussed in brief in Appendix 2.

Reason for Choosing the Two-sided Matching Algorithm. The two-sided matching algorithm is chosen because it promotes stable matches, which is key to the success of this process. Although the two-sided matching algorithm does not produce pareto optimal solutions for the commands, the matches are stable. The matches also allow commands to get their best ranked sailors from among those who list them in their preference lists. In effect, there is a tradeoff between billets' preferences (satisfaction) and sailor satisfaction. However, if sailors choose to list billets for which they are well ranked, sailor and command satisfaction are no longer completely dichotomous and divergent in interests. As sailors and billets choose each other, the two-sided matching solutions will tend towards the optimal solutions that maximize both commands' and sailors' satisfaction. This can be seen in a simple example of two billets and two sailors : Billet A ranks sailor X first and sailor Y second, and billet B is the opposite, ranking sailor Y first and sailor X second. After looking at these, their rankings, in JASS+, sailor X decides to rank billet A first and billet B second, and sailor Y is the opposite - ranking billet B first and billet A second. The two sided matching algorithm will match sailor X to billet A and sailor B to billet Y. All parties get their first choices, producing a result that is optimal for all parties.

The Four Phases of the Two-Sided Matching Process. The two sided matching process has four main phases. First, all distributable sailors are matched against all available billets. Secondly, adjustments are made for tied movers to ensure these couples are assigned to billets in the same location. Thirdly, the matching is run again with the remaining sailors and billets. Sailors and billets that are not matched after this are carried forward to the next cycle. Fourthly, exceptions are managed where billets and sailors that are not matched in the past 2 cycles are forcibly matched, with priority billets being forcibly matched first. These 4 main steps of the process are detailed in Figure 6 on the next page.

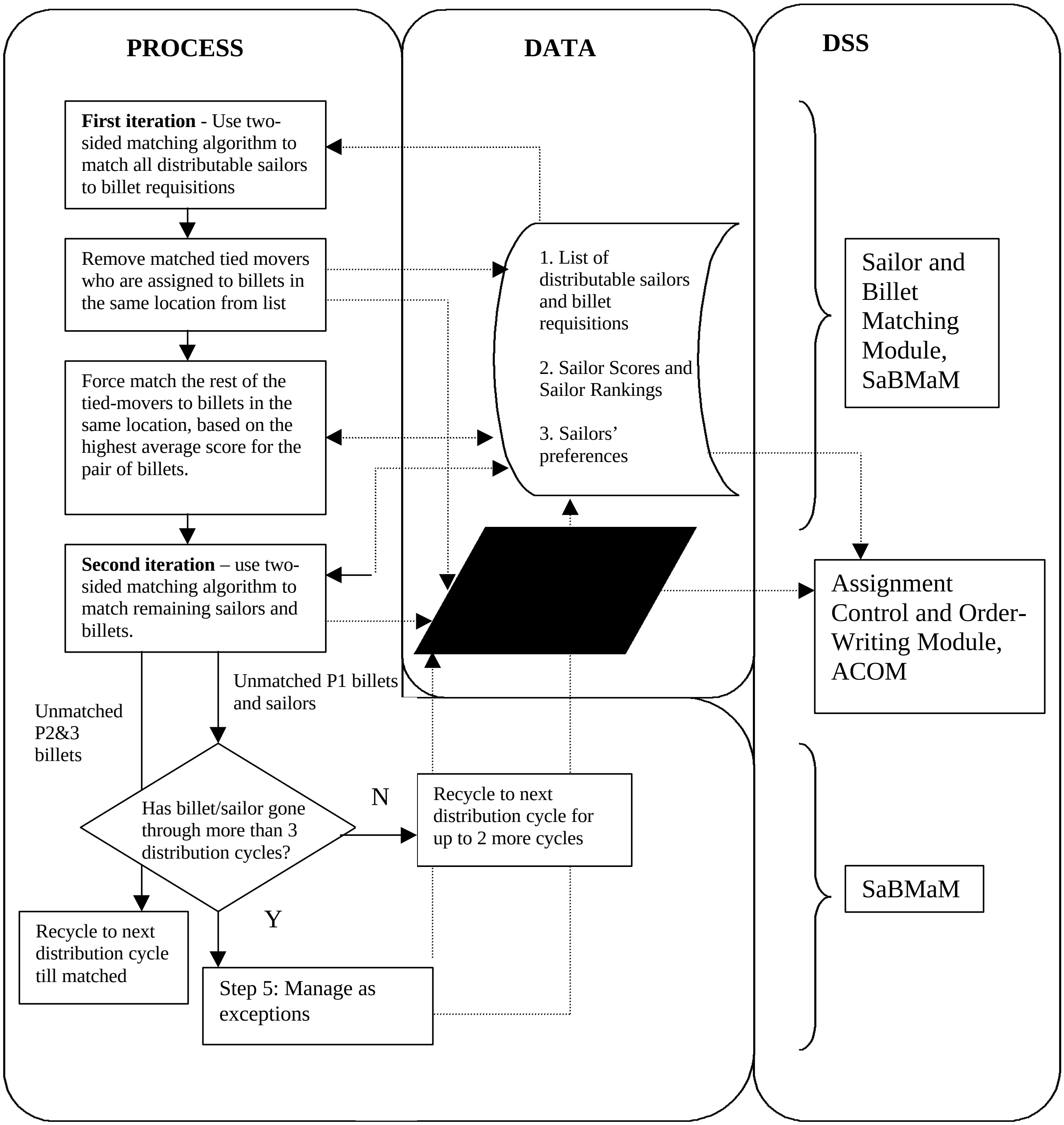

Figure 6 – Step 4 : Sailor and Billet Matching Process

Increasing the Interval Between Distribution Cycles to One Month. Currently, the interval between cycles is two weeks, where about 15,000 to 17,000 sailors are matched to billets per cycle. However, if we consider that the matching is done separately for each different rating and paygrade, the numbers that are to be matched in each category are not large. Currently, each of the 300 or so detailers who are responsible for each separate category handles about 50 to 60 sailors and billets per cycle. The interval should be increased to a month long cycle to increase the number of sailors and billets available for matching. This will in turn increase the proportion, quality and stability of the matches. However, the tradeoff is that billets and sailors that are not matched cannot be carried over for too many cycles, as they would get too close to their PRDs. Ideally, sailors should be informed of their next assignment five to six months before their rotation date.

Three Month Long Cycles to be Matched. As the cycle starts nine months out from PRD, and it takes some time for career counseling and listing preferences, three to four months are available for billets and sailors to be matched. If billets and sailors go through the distribution cycle three times over three months before they are forcibly matched on the fourth month, they can still be notified of their assignments at least 5 months out. Given the larger number of billets and sailors available over a month long cycle, the incentive for sailors to choose billets in which they rank well, and the need to include priority 1 and 2 billets in their preference lists, it is likely that all sailors and billets will be automatically matched by the process within three iterations, so that commands will be notified of the assignments 6 months out.

Matching Phase 1 - First Iteration of Two–Sided Matching Run With All Sailors. Each round of the matching process has two iterations to take into account tied movers. In the first iteration, SaBMaM makes an initial run for the entire population. The system must make corrections to the initial matches of tied movers who are assigned to different locations to reassign them to billets in the same location. After the initial matching run is completed, the matches of each pair of tied movers are examined. If any tied movers are matched to billets in the same location after the initial run, these pairs of sailors and the billets are removed from the list to be run for the second iteration.

Matching Phase 2 – Adjusting the Matches for Tied Movers. Next, the tied movers that have billets in different locations are then examined. SaBMaM looks at each of the married sailor's ranked positions in the billets to which they are tentatively matched. For example, after a first matching run in SaBMaM, sailor A may be tentatively matched to billet X in Hawaii, where he is ranked number 3 for that billet (based on the scoring and ranking process earlier). However, his spouse, sailor B, may be tentatively matched to billet Y in Virginia where she is ranked number 4 for that billet. SaBMaM then looks at the highest ranking of a billet for which each partner is eligible in the location where his/her spouse is matched. In this example, SaBMaM looks at the highest ranked billet for sailor A in Virginia where his spouse, sailor B, is tentatively matched - suppose he is ranked number 10 for a billet XX in Virginia. Likewise, SaBMaM looks at sailor B's ranking in a billet YY in Hawaii – say she is ranked number 7 for that billet. SaBMaM then computes the average total ranking and assigns the couple to the billets in the location with the lowest average rank. In this example, the average rank for this couple in Hawaii is (3 + 7) /2 = 5 and for Virginia is (4 + 10) /2 = 7. Therefore, the couple will be assigned to Hawaii with sailor A being assigned to billet X, and sailor B assigned to billet YY. This iterative process ensures that the commands get the best average ranked scores whilst taking into account tied movers. On average, commands get assigned pairs of sailors that score the highest as a pair after taking into account the tied mover pairs' preferences.[7] This phase ensures that all tied movers are matched first and removed from the list of distributable sailors for later iterations. Likewise, billets matched to tied movers in this phase are removed from the list of available billets. The remaining sailors (non tied movers) and billets are then run again in a second iteration.

[7] There may be problems with stability in this process as one of the tied movers is given priority over non tied movers in assignments. In this example, billet YY may prefer another sailor over sailor B, and sailor B may prefer another billet over billet YY. In this process, sailor B is force matched to billet YY even if another sailor could have been tentatively matched to billet YY. However, as tied movers agree to move together, from the sailors' end, the stability issue among tied movers is mitigated although stability is degraded among non tied movers. Sailor B would not seek out a billet in another location as her interest of being assigned to the same locality as her spouse is fulfilled. There would still be residual instability on the commands end. However, as the proportion of tied movers in the Navy is not large, this problem is not seen to degrade overall matching stability by a significant degree.

Roth and Peranson (1999), in their design of the matching market for American physicians, describe an alternative for dealing with tied movers. This alternative, its benefits and shortcomings, is described in more detail in Appendix 3. Although their design promotes stability in the matches, it penalizes the tied movers by 'bouncing' them lower down their preference list. The process described above does not penalize tied movers but trades off some stability. This tradeoff between 'stability' and 'prioritization' is a dilemma to be considered. An empirical examination will have to be conducted to further appreciate the impact on stability of adopting the 'highest average score' method proposed above as compared to Roth and Peranson's design. However, given the small number of tied movers, it is felt that the decrease in stability will be slight. It is a small price to pay in order to protect the welfare of tied movers.

<u>Matching Phase 3 – Second Iteration of Two-Sided Matching : Run on All Remaining Sailors</u>. After tied movers are matched and removed from the matching system, all the remaining non-tied mover sailors and billets are matched again the second time using the two-sided matching algorithm. Sailors on EFMP will be included in the entire distributable sailor pool for matching. EFMP sailors are already given priority for assignments in billets through the scoring process compared to non-EFMP sailors with similar attributes. The two-sided matching process will consider this prioritization in the scoring.

<u>Matching Phase 4a – Ensuring All Sailors are Matched</u>. After the second round of matching occurs (phase 3), there will be some sailors who are not matched by SaBMaM, as they may be beaten in all their preferences by other sailors. SaBMaM will be smart enough to provide summary information of why a specific sailor fails to be matched and provide advice on how he can restate his preferences to stand a better chance for a match. For example, it may detail that the sailor did not list billets to which he had a high chance of being matched. Detailers will have to contact these sailors to advise them on their situation and counsel them on what changes they need to make to their preference lists to stand a better chance in getting matched. Unmatched sailors will be carried forward to the next cycle where they will be run through the entire distribution process again. In the next

distribution cycle, they will be included in the distributable inventory, screened and scored by billets and sailors, and matched again. After the third try, sailors and who fail to match with the two-sided algorithm will be managed as exceptions and matched using an optimization algorithm (Step 5), which could mean that they get matched to jobs they do not prefer. The detailer will contact the sailor again and explain the situation. Given the larger number of billets that sailors have to list in their preference, the education of sailors to choose billets for which they rank well, and the three rounds of two-sided matching that they undergo, the numbers of such unmatched sailors after three rounds is expected to be small.

<u>Matching Phase 4b – Dealing with Unmatched Billets</u>. As with sailors, some billets may be unmatched after the first cycle. In dealing with unmatched billets, the priority of the billets will have to be considered. Priority 1 billets have to be manned at 100%. As they are projected to be vacant nine months later, they need to be assigned a sailor at the latest five months out, as the assigned sailor needs at least five months notice of an impending move. This affords priority 1 billets three tries to be matched by the system before they must be managed as an exception and assigned a sailor (i.e. unmatched priority 1 billets can be recycled two more times after the first cycle before they are managed as exceptions). For priority 2, 3 and non-priority billets, they need not be 100% manned. Therefore, they can be recycled indefinitely in the redesigned distribution process. Placement officers can increase the chances of such billets being matched by changing their desired sailor attribute weights and relaxing their billets' requirements. This will improve the scoring and ranking of the sailors, and increase the number of sailors that are eligible for the job, thus increasing the probability of the billet being matched. Some billets may not be matched even if they relax their requirements, as they have attributes that are undesirable to sailors. For example the billet may be in a remote location. SaBMaM will identify these undesirable billets if they continually fail to be matched. At the end of every monthly distribution cycle, NERISSA will produce a list of such billets as part of the summary / audit report for EPMAC. EPMAC can then use this information to recommend policy changes to enhance the attractiveness of such billets, like recommending assignment bonus benefits, and/or awarding bonus points for

the next assignment.

Meeting NMP Manning Targets. SaBMaM will keep an internal count on the number of matches for each billet priority, command and ratings class to ensure that the resultant manning level for each MCA does not exceed those detailed in the NMP. Recall that the NMP is a prioritized manning plan generated in the allocation process to ensure commands get their required fair share of the distributable inventory. It also ensures that all distributable sailors will be assigned a billet. Those not assigned a P1 billet will be assigned to a P2, P3 or un-prioritized billet. After reaching the desired manning level for a priority class, all the remaining billets of that priority class will be removed from the list and brought forward to the next cycle. For example, there may be 100 priority 2 E4 corpsmen billet requisitions in the current cycle. Assume that the NMP dictates that only 80 of these billets should be filled to meet an overall target manning percentage of 80%. SaBMaM will remove the remaining 20 billets from the matching list after the eightieth billet is matched. These 20 billets will be included in the next cycle and have another chance to be matched. If 90 sailors are matched to 90 of the 100 billet requisitions (10 more than the 80 required), the 'worst' 10 matches will be un-matched and the sailors and billets recycled to the next matching cycle. The 'worst' matches are those billets that are tentatively assigned sailors that are lowest in their ranking list. If the matching run produces matches that fall below the targeted manning level, unmatched billets in that priority level will be recycled to the next cycle to be matched again. SaBMaM will tag the billets to its cohort and keep track of the manning achieved for that cohort to ensure that the manning targets are met. Even if the billets in an earlier cohort are recycled to a later matching cycle that may contain billets from a newer cohort (with different manning targets), SaBMaM will ensure that manning targets for different cohorts are met.

Summary Of Step 4. In Summary, The Two-Sided Matching Process Phase Can Be Described As Follows **:**

- **Input** : Ranked commands' preferences of sailors (from SaBiSS). Ranked sailors' preferences of billets (from JASS+).
- **Process** : Both the sailor's preferences and the command's preferences are

tentatively matched using a two-sided matching technique (done by SaBMaM). Tied movers are forcibly matched to the same location and removed from the matching list. The remaining sailors and billets are matched again. Unmatched sailors and priority 1 billets are recycled to the next distribution cycle to be matched again for up to 2 more month long distribution cycles. Priority 2, 3 and non-priority billets are recycled indefinitely until they are matched.

- **Output** : Matched pairs of billets and sailors. A list of unmatched sailors and priority 1 billets after 3 cycles are produced and managed in Step 5.
- **IS/DSS Introduced** : Sailor and Billet Matching Module (SaBMaM).

7. Step 5 : Exception Management, Auditing, and Orders Writing

Three lists are produced after step 4. The first list details the pairs of sailor-billet matches that are assigned with the two-sided matching algorithm. The second list is the unmatched priority 1 billets that need to be assigned a sailor after being ‘passed over’ in the previous three distribution cycles. The third list details the sailors who have not been matched after three cycles and need to be assigned a billet. With the redesigned process, unmatched billets and sailors lists are expected to be short and are managed as exceptions. First, they are matched by using an optimization algorithm, and as a last resort, they are managed manually. After all the sailors and priority 1 billets are matched, the completed lists of sailor-billet matched pairs are compiled into a summary report for auditing by EPMAC to ensure manning targets and policies and met. After EPMAC makes the necessary changes to the assignments, the finalized list is approved. Orders will be electronically ‘written,’ recorded, and sent to sailors, commands, CCCs and placement officers, thus completing the entire MPT distribution cycle. This process is summarized in Figure 7 on the next page.

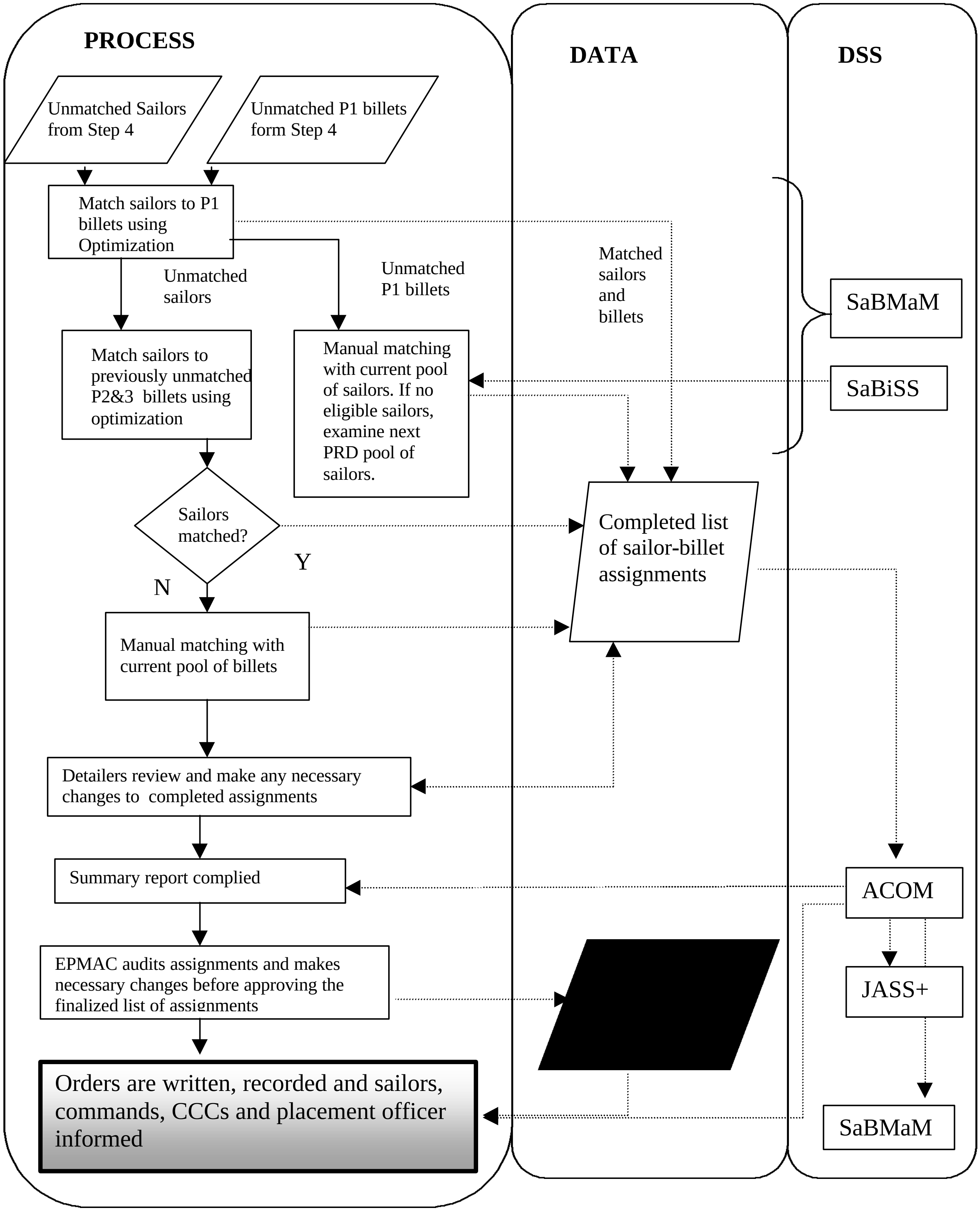

Figure 7 – Step 5 : Exceptions Management, Auditing and Orders Writing

Matching Previously Unmatched Sailors and Priority 1 Billets Using an Optimization Algorithm. In managing these exceptions, SaBMaM will first match the unmatched sailors to the unmatched priority 1 billets. Sailors can be unmatched if they are beaten in all their preferences by other sailors. The P1 billets that remain unmatched include those that the unmatched sailors do not list in their preferences. Therefore, the process will force match these sailors and P1 billets. An optimization algorithm will be used to match them and it seeks to maximize the sum of the total sailors' scores of the matches. The sum total of sailors' scores is defined as the summation of every sailor's total weighted attribute scores. Algebraically,

$$\text{Max : Sum of Total Sailor Score} = \sum S_{ij}^{T}$$

Where :

S_{ij}^{T} is the total sailor score of sailor i, derived from the comparison of his individual attributes and billet j's requirements.

In effect, the optimization algorithm seeks to maximize the commands' satisfaction (as measured by the total sailor scores, S^T). Unlike the two-sided matching algorithm, the optimization algorithm may assign a sailor to a billet even if the billet is not in the sailor's preference list. This will forcibly match sailors to billets who state their preferences without regard to their rankings or sailors who are gaming the system to 'try their luck' with their most preferred choices. However, SaBMaM will only match sailors to billets if they are eligible based on the billet's 'Must Have' attributes. Instead of manually managing exceptions, this method ensures an objective and accurate method of dealing with these exceptions that is in line with Navy manning and personnel policy while ensuring that most of the remaining sailors and priority 1 billets are matched.

Dealing with Unmatched Sailors and Billets after the Optimization. The optimization will produce one of two possible outcomes : 1) if there are more eligible sailors than priority 1 billets, there will be some sailors left unmatched; 2) if there are fewer eligible sailors than priority 1 billets - caused by a mismatch of sailors' and billets'

‘Must Have’ requirements and/or outright shortfall of sailors - there will be some billets left unmatched. In the first case, SaBMaM will use the same optimization algorithm and attempt to match these sailors to priority 2, 3 and non-priority billets that were previously unmatched and recycled in the last 3 cycles. Any other sailors that are still unmatched after this will be manually matched to the current pool of billets by the detailers. This number is expected to be very small and are likely to be sailors with peculiar issues that are difficult to manage by the automatic system and requires closer attention from the detailers and CCCs. These may be sailors who lack the skills required in most of the billets and therefore need to attend some training courses. In the latter case, priority 1 billets left unmatched even after so many rounds of matching will be manually matched with the most current pool of sailors. These billets are also expected to be very few. Detailers are assisted in the manual matching by SaBiSS, which will screen the current pool sailors for eligibility.

If yet no sailors are eligible, detailers can use NERRISSA to look for sailors coming up for distribution in the next cycle (i.e. those who PRD in 10 months) who are eligible and recommend them for early PRDs if they can be matched to these priority 1 billets. EPMAC will receive a list of these difficult to fill billets for each distribution ‘cohort’[8] and examine them for why they are so difficult to fill. The requirements of the billet could be too demanding resulting in too few qualified sailors. If this is the case, job requirements should be reviewed for these billets.

<u>Auditing and Confirming the Matching Results, and Writing the Orders</u>. After each cycle, the SaBMaM-matched pairs of sailors and billets from the two sided matching, optimization and manual matching phases will be recorded. This tentative, but ‘nearly there’ matched list summarizing all the assignments will be produced for each cognizant detailer. Detailers will have the option to override the system through a manual Change Handling Screen on SaBMaM, and change matches if necessary. This should be strongly discouraged except in exceptional situations (e.g. when a dire requisition

[8] A ‘cohort’ is defined as the group of distributable sailors and billet requisitions identified by EDPORJ nine months out

suddenly arises and needs to be filled immediately, in which case a sailor may be diverted to fill the urgent requisition).

After any changes by the detailers, the list with a summary report will be sent to EPMAC for final approval. A summary report of successful and unsuccessful matches, and quality of matches (e.g. median ranked preference of assigned sailors and billets, proportion matched by two-sided algorithm and forced matches) will be electronically sent to EPMAC for auditing purposes. EPMAC then ensures that the system is running smoothly by monitoring the quantity and quality of the matches, and most importantly, that the assignments meet the NMP's manning targets. EPMAC will hit the 'Approved' button, which will then automatically produce the assignment orders. The assignment orders will be sent to the sailors, commands and CCCs via e-mail, and the CKBS. EPMAC should then examine the summary data to identify any needed adjustments to the process itself or its policies.

<u>Assignment Confirmation and Order-Writing Module, ACOM</u>. All this information is handled through a module in NERISSA called the Assignment Confirmation and Order-Writing Module, ACOM. ACOM accepts the detailer-finalized matches and compiles the summary report for EPMAC. EPMAC accesses the summary report through ACOM, makes any required changes to the assignments, documents the reason for the changes and finally approves them via ACOMS. ACOMS updates the lists of distributable sailors and billet requisitions, updates SaBMaM, EMF and TFMMS for the assignments made, and generates the formal assignment orders to be sent electronically to sailors and commands via e-mail and CKBS. JASS+ is also updated to allow sailors to track the progress of their application. The finalized matched sailor-billet pairs are removed from the distributable sailor list and billet requisition list in SaBMaM. The sailors and billets in the 'unmatched' lists in SaBMaM are recycled to the list of distributable sailors and billet requisitions in the next distribution cycle. Together with SaBMaM, ACOM replaces the Orders-Writing Module (OM) in the Enlisted Assignment Information System (EAIS), currently used by detailers to manually assign sailors to billets. It also negates the need for manually writing paper orders, as it is done now.

Matching Tied Movers With One Party Who is an Officer. As Navy officers are matched using manual assignment process, tied movers who are enlisted-officer couples need to be managed manually as exceptions.

Dealing with Sailors Who Do Not State Their Preferences. Some sailors may not state their billet preferences. Some may genuinely not have any preferences and be indifferent about where they will be assigned next. Some may not have been duly informed that they are due for PRD or are not clear about what to do next and how to list their preferences. Controls need to be put in place to ensure that all sailors have a fair chance to state their preferences. CCCs play a key role in educating uninformed sailors. Although the process primarily places the onus on sailors to make an appointment with their CCCs (thereby symbolizing that sailors too are responsible for managing their own careers), CCCs must also play an active role in approaching sailors who do not schedule an appointment. Therefore, if sailors do not make an appointment with their CCCs one week after being informed that they are due for rotation, CCCs must contact them. JASS+ will automatically alert CCCs of such sailors. This will ensure that sailors who did not get the message for whatever reason will not be left out of the process and have a chance to see their CCC. Only after CCCs confirm that they have seen the sailors through JASS+, can the system include these sailors for matching in the current cycle. For sailors who do not state preferences because they have none, their 'preferences' will be defaulted to the billets for which they are highest ranked.

Dealing with Current 'Sailor Priority' Programs. There are several programs currently in place to give sailors priority in their assignment choices. GUARDS III assigns sailors to the location or ship type of their choice in exchange for the sailors' commitment to extend their contracts. The TWILIGHT program similarly assigns very senior enlisted personnel to their location of choice as their last duty station before retirement. For the sailors in these two programs, SaBiSS will only include locations or ships that the sailor prefers in the list of eligible billets. They will also be awarded bonus points for these billets in their sailor scores. This ensures that they are given priority in

being matched to these billets. Even if they fail to be automatically matched to these billets after 3 cycles, they can be manually matched to the locations or ships of their choice.

SWAPS is another ‘sailor priority’ program where enlisted sailors are allowed to mutually swap billets with each other if both they and their commands are agreeable. This can only occur after the official orders are sent out, and therefore does not affect the process. After their initial assignments, sailors who can mutually agree to swap billets will contact their CCCs, who in turn will contact the detailer in charge of that rating. The detailer will coordinate the desired changes with the commands. The detailer will also check if the changes satisfy the manning and personnel policies. If all parties are agreeable, the detailer will make the changes in the Change Handling Screen in SaBMaM and the new orders will be sent via ACOM to the sailors and commands. It is noted that if matches are stable, sailors will not seek to swap positions, unless they change their minds after receiving their assignments – ‘buyer’s remorse’ may set in. In the redesigned distribution process, most of the matches are stable and swapping positions will be a rarity.

<u>Identifying Deploying Units’ Requisitions 18 months Out</u>. A recent EPMAC change in the distribution policy is to project requisitions for deployable units (e.g. ships) 18 months out instead of the current 9 months. This ensures that the units’ full complement of sailors is on-board at least 6 months before deployment, enabling the unit to build up its teamwork, sailors’ OJT skills and overall readiness. It seeks to avoid having any ‘newbies’ in these units just before or during the deployment. The recent change also gives an increasing ‘priority boost’ to requisitions as they approach the D-9 (read: D minus 9, or 9 months before deployment) timeline. The redesigned process is robust enough to start rotating new sailors into deployable units 9 months ahead of deployments. The allocation process has to identify these billets 18 months out instead of the current 9 months. This requirement can easily be input into EDPROJ. The rest of the process remains the same as that described in this chapter. As deploying units’ billets are priority 1, the redesigned process ensures they are filled by the third distribution cycle

(i.e. within 3 months of the requisition being raised). At the worst case, they will be manually assigned a sailor within a month after the third cycle if they fail to receive an automatic assignment. At the worst case, deployable units and sailors will be informed of their sailors and units, respectively, 5 months before PCS (i.e. 14 months before deployment).

8. Timeline and Schedule for Activities

The timeline for the distribution process is driven by the goal of informing sailors and commands between eight to five months out of the sailors' PRD date (i.e. between P-8 and P-5 months where 'P' is the PRD date). The constraints of the process are that projections of distributable sailors and billet requisitions are made nine months out and each entire distribution cycle lasts 1 month. In brief, the timeline follows this general sequence: nine months out, the allocation process begins to project sailors and billets for rotation and requisitions, respectively; sailors are then informed of their PRDs and commands (via the placement officers) are informed of their billet requisitions; the NMP is produced within a week; and sailors have two weeks from being informed to meet with their career counselors and state their preferences in JASS+. In the fourth week of the distribution cycle, the matching is done and assignments confirmed. Sailors and billets matched then will be informed at the start of P-8. Those not matched will be recycled to the next month long distribution cycle. By the end of the third cycle, exceptions from the first cycle will be manually handled. This takes up to a month, and by end of fourth month, P-6 (i.e. start of P–5), the exceptions are resolved and all the distributable sailors and P1 billets identified at P-9 are assigned. The timeline and activity schedule for the process is detailed in table 4. It summarizes the process for one 'cohort' of sailors and billets identified nine months out.

Table 4 – Timeline and Schedule of Activities

	TIMELINE / ACTIVITY					
	P-9			**P-8 & P-7**	**P-6**	**P**
ACTOR	**Wk 1**	**Wk 2 & 3**	**Wk 4**			
EPMAC	Run EDPROJ to project distributable sailors and billet requisitions for PRD at time 'P'. Produce NMP. Run SaBiSS to screen sailors.		End Wk 4 – Audit and approve finalized assignments. Order written.	Repeat monthly distribution cycle.	Repeat monthly distribution cycle.	Repeat monthly distribution cycle.
Placement Officers/ Commands	Input billet requirements into PlaceS.		End Wk 4 – Commands informed of assignments.	Unmatched billets recycled.	Unmatched P1 billets manually matched by end P-6. Other unmatched billets continue to be recycled.	Billets receive sailors.
NERISSA	SaBiSS scores sailors and downloads sailor rankings into JASS+.	CKBS produces personalized career advisories	Start Wk 4 - Matching runs are done on SaBMaM.	Matching runs are done on SaBMaM.		
Sailors	Sailors are informed via e-mail and CCCs.	Meet with CCCs and input preferences into JASS+.	End Wk 4- Sailors are informed of their assignments. Sailors not matched are recycled.	Sailors reenter preferences based on latest list on JASS+. Sailors not matched are recycled.	Unmatched sailors are manually assigned. All sailors are assigned by end P-6 and informed of their assignments.	All sailors PCS to their new billets.
Detailers			Start Wk 4 - Run matching program, SaBMaM.	Start Wk 4 - Run matching program, SaBMaM.	Manage exceptions and manually match unmatched sailors and P1 billets.	
CCC		Counsel Sailors.	End Wk 4 - Inform sailors of finalized outcome.	Counsels unmatched sailors from previous cycle.	Informs sailors who are manually matched of the finalized outcomes.	

Note: P = PRD Date. P – 9 means 9 months prior to PRD

B. DECISION SUPPORT SYSTEM MODULES AND DESIGN

NERISSA is a tightly integrated decision support system that employs a modular approach to its design. The modules share information electronically with one another, dispensing with the need for multiple data entry and paper shuffling. The different modules of NERISSA are integrated to provide the redesigned process a seamless flow of information that is accurate, current and organized. Information that is entered or changed will be immediately reflected throughout the system. NERRISA integrates new modules with current databases like the EMF, TFMMS and Navy training management catalogues. This allows for a shorter start up time for system implementation, as the large quantities of sailor, billet and training data need not be recreated but can be immediately tapped and utilized by the system.

NERISSA's suite of application modules is presented in a single integrated package that allows for easy installation, easier switching between applications by users, and easier maintenance and upgrades. Much like an internet banking web-site where users can perform product queries, banking transactions, and even link with external systems like stock purchases and sales, NERISSA's modules perform multiple tasks to be performed on a single platform. Users are limited in their access to their modules by unique user ids and passwords. For example, sailors can access only JASS+ while EPMAC can access all the modules. NERISSA resides on the Navy Marine Corps Intranet (NMCI) infrastructure and can be delivered securely to all users who have access to the NMCI on shore installations or at sea. The different modules are described in Table 5 below and their linkages with each other and other key external systems are described in Figure 8.

Table 5 – Summary of NERISSA Modules' Description

Module	**Purpose**	**Users/ Access**	**System Input from**	**Data Produced**	**System Output to**
EDPROJ, Enlisted Distribution Projection System	Projects billet requisitions and PRDs x months out. Identifies billets that need sailors and sailors that are due for PRD x mths out.	EPMAC	EMF, TFMMS	Distributable Sailors, Billet Requisitions	JASS+, SaBiSS, CKBS
SaBiSS, Sailor and Billet Screening and Scoring System	Screens sailors for eligibility based on the billets' 'Must Have' requirements and scores eligible sailors based on 'Should Have' requirements.		EMF, TFMMS, PlaceS	Scores and ranked list of Sailors for each Billet.	JASS+, SaBMaM
PlaceS, Placement System	Allows users to enter the commands' qualitative requirements of sailors i.e. update their billets' 'must have' and 'should have' requirements and their weights.	Placement Officers, EPMAC	TFMMS	Scoring Tables for SaBiSS.	SaBiSS
JASS+, Job Advertising and Selection System Plus	Allows sailors to view all the billets for which they are eligible and their scores and ranking, get job descriptions, schedule appointments with their CCCs, apply for billets by listing their preferences, and track their progress.	Sailors, Detailers, Placement Officers, EPMAC	SaBiSS	Appointment schedule with CCCs, Sailors ranked preferences of billets.	SaBMaM

Table continued…

Module	Purpose	Users/ Access	System Input from	Data Produced	System Output
CKBS – Career Knowledge Based System	Assists CCCs in counseling sailors. The system allows sailors to score billets based on their preferences and produces personalized career advisories by drawing on a library of resources and databases. It also has an online career management resource library with search features into which CCCs can tap.	CCCs, Detailers EPMAC	SaBiSS, TFMMS, EMF, Online Career Manage ment Resource Libraries	Personalized Career Advisories.	
SaBMaM, Sailor and Billet Matching Module	Matches sailors to Billets based on billets' and sailors' preferences. First a two-sided matching algorithm is used. Unmatched sailors and billets are matched with an Optimization algorithm. Finally still unmatched sailors and key billets are manually matched online.	Detailers, EPMAC	SaBiSS, JASS+, EMF, TFMMS	Tentative matched sailor-billet pairs, a list of unmatched billets and sailors.	ACOM
ACOM Assignment Control and Order-Writing Module	Receives matched sailors-billet pairs information and complies a summary report detailing quantity and quality of matches. Allows EPMAC to audit the outputs, make changes to the assignments and electronically approve. The approved list of assignments is then recorded and orders written and sent electronically to sailors, commands and CCCs.	EPMAC	SaBMaM	Approved list of matched pairs. Finalized assignment orders.	EMF, TFMMS, SaBMaM

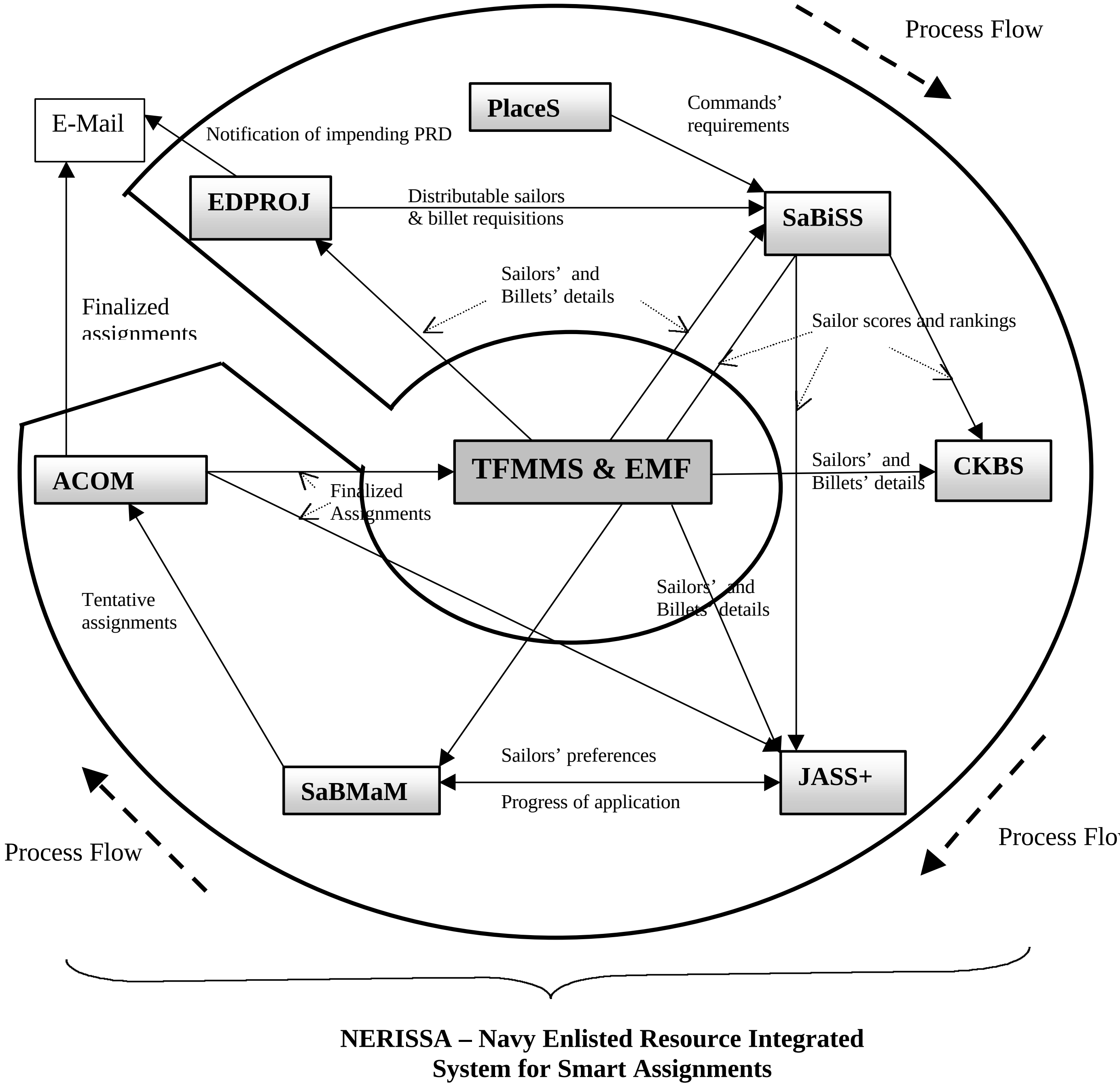

Figure 8 –Network Diagram of NERISSA

C. BENEFITS AND SHORTCOMINGS OF THE REDESIGNED PROCESS

1. Benefits

The benefits of the redesigned process are examined with regards to the critical success factors (CSFs) and constraints detailed in chapter three. The degrees to which the redesigned process satisfy the CSFs within the constraints are discussed in this section.

Smooth, Timely, Complete and Accurate Information Flows. Through NERISSA, the redesigned process streamlines information flows and radically improves on the timeliness and accuracy of the capture, transfer, processing and delivery of important information to the users. As the information is organized and transferred electronically within an integrated information system, the latest information is accurately captured and transferred immediately to all NERISSA modules. Users who need information to make decisions can access this information easily and in a form that is collated into easily understood and digestable portions. For example, sailors can access JASS+ to look at pertinent information on billet choices that is personalized to them based on their eligibility. The CKBS's ability to generate personalized career advisories is also a good example of the process's ability to deliver quality useful information to the users - sailors and CCCs. The plethora of sailor and billet requirements are also efficiently managed by the scoring and matching process and DSS modules without human error or bias. This contrasts with the current process where information is unevenly distributed, not as easy to access, and at times inaccurate.

Sailors Expectations And Needs Are Managed And Met. In the redesigned process, sailors' needs and preferences are solicited and are key in the matching process. In the two-sided matching algorithm, sailors will not be matched to billets that they do not state as one of their preferences. Sailors who are manually matched as a last resort are counseled by CCCs who have the information on NERISSA to explain why they have failed to be assigned a billet. The process also manages sailors' expectations by educating them on their chances for being assigned to billets based on objective measures and

updated policies. Here, the counseling process and information presentation tools (JASS+ and the CKBS) play a key role in assisting the CCCs to educate sailors on the realistic career decisions that they should make. The sailor is provided with information on their standing, the process itself and their progress in the assignment cycle. All this information and counseling will moderate sailors' expectations and their choices. This greatly improves the chances of the Navy fulfilling them and hence resulting in higher satisfaction.

Trust In the Objectivity And Reliability Of The Process. The consistency of the redesigned process is a quantum improvement from the current process that is plagued by perceptions of subjectivity and inconsistency. In contrast, the redesigned process is a logical process that employs a consistent set of standards and procedures that is encapsulated in a computer system for assigning sailors to billets. Through educating users on how the assignments are made, and the consistency of the resulting assignments, users will come to trust in its objectivity and reliability. The process also enhances sailors' perceptions that they are all treated equally based on published policies.

A High Proportion of Automatically Matched Sailors And Billets. The redesigned process automatically matches sailors to billets over a maximum of three cycles. The chances of being matched within the three cycles is improved by having a larger pool of sailors and billets in a month long interval, compared to the previous two week long interval. Encouraging sailors to choose their billets wisely also improves the chances that they will be automatically matched. The disincentive of being forcibly matched and possibly assigned to a non-preferred billet will likely push sailors to choose their billets more realistically. Increasing the proportion of sailors automatically matched minimizes the need to manually assign sailors to a billet.[9] The process also fulfils the constraint that all sailors must be matched to a billet, as the small number not automatically matched are manually managed as a last resort.

High Quality Of Matches. On the whole, the current process produces high quality matches from the command's viewpoint but lower quality matches from the sailors' viewpoint (i.e. we have emphasize the commands' needs). The redesigned process sees a quantum improvement in the quality of matches as it is able to concurrently meet the need for quality matches from both sailors' and commands' perspective by considering both parties' preferences. As the process assigns only eligible sailors to billets, commands can be assured that they will receive only sailors who qualify for the minimum job requirements. The process also adheres to the manning targets spelt out in the Navy Manning Plan, and importantly, priority 1 billets are filled. Only sailors who make unrealistic choices and sailors who have unique attributes may end up being forcibly matched by optimization or manual means, resulting in command biased matches. Even then, the quality of the matches are assured from at least the commands' side.

Stability Of Matches. The assignments completed by the two-sided algorithm are stable matches. This is important to enhance both sailors' and commands' satisfaction. However, not all the matches in the process are stable. For example, tied movers who are forcibly matched to the same location will likely assign one of the parties to an unstable match. Also, as tied movers are matched to billets by the 'highest average total rank' method described above, they may be assigned to a preferred billet of another sailor, leading to another unstable match involving the denied sailor with another billet of lower preference. There are some sailors who may be matched by optimization or manual methods as a last resort. These matches are also unlikely to be stable. This tradeoff of some matching stability for process flexibility is inevitable in order for the process to cope with exceptions and to ensure that all sailors are assigned a billet. However, tied movers and sailors matched via optimization or manual methods are likely to be a small proportion of the total sailors and billets matched in the process. The large proportion of the matches are still stable after discounting for the billets and sailors managed as exceptions.

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[9] Further studies will have to be conducted to study the likely proportion of matches using this process in a variety of scenarios. Questions of "How high a proportion is high enough?" can be a subject of

Flexibility To Deal With Exceptions And Dynamic Changes. The process is robust enough to deal with most of the more common exceptions, like tied movers, sailors in EFMP and ‘sailor priority’ programs. The need to fill priority billets is also addressed in the process as priority 1 billets are ensured an assignment by the end of P-6. However, there are still process limitations and other unique exceptions, like enlisted-officer pair tied movers and urgent inclusions of billet requisitions that need to be filled quickly, will have to be dealt with manually. Even then, detailers are assisted in manual assignments by using sailor and billet information from NERISSA to screen sailors for eligibility. Dynamic changes in billet requisitions that occur in mid-cycle can be handled to some extent by the process. For example, deleted billet requisitions can be automatically removed from the list of billets to be matched in JASS+ and SaBMaM. However, including newly arising billets in mid-cycle will have to be delayed until the next cycle. Although these billets can be included in NERISSA in mid-cycle, sailors who have already stated their ranked preferences would have to go back to reconsider a new billet inclusion. This is impractical; if the billet requisition is not urgent, it will have to be delayed till the next cycle.

Maintain The Human Touch. The redesigned process enhances the interaction between commands and sailors through the career counseling process. Although much of the process is now automated, the career counseling phase is key in maintaining a human touch in the process. Career counseling is mandatory in the process and sailors cannot state their preferences until they meet with their CCCs. CCCs also serve as a accessible common point of contact for sailors who no longer deal with multiple agents (CCCs, Detailers, and commands). With the CKBS in NERISSA and the personalized career advisory as a guide, CCCs have the information to understand the sailors’ backgrounds, their career path requirements and the opportunities available for the sailors. CCCs will now have the tools to make the interaction with sailors a value added experience for the sailor. In time, CCCs will be perceived by the sailors as representatives of the Navy who are there to counsel sailors on how best to manage their own careers. This will greatly

further studies and surveys.

enhance the Navy's paternalistic culture while concurrently promoting the sailors' self-responsibility for their own career.

Labor and Costs Savings. Labor requirements and costs can be greatly reduced with this new process, as most of the transaction-based activities are automated. Most of the labor in the current process is concentrated in the detailer shops, where there are close to 300 detailers. As most of the detailing process is now automated, the number of detailers can be greatly reduced. Their task is concentrated on managing exceptions. Apart from labor cost savings, costs can also be reduced by having fewer diverts, paper shuffling and phone calls. PCS costs are also managed as an item that the process seeks to minimize in the sailor scoring metrics.

2. Shortcomings

The shortcomings of the redesigned process arise mainly because the system has to be robust enough to balance the need to manage exceptions, match all sailors and priority billets, deal with the variability of sailor behavior and decision making, and the need to have stable matches. These requirements are sometimes at odds with one another and tradeoffs may have to be made. The shortcomings of the redesigned process are discussed next.

Not All Matches are Stable. As discussed above, not all the matches are stable in the redesigned process, because of the need to deal with exceptions. This tradeoff is justified by the process's ability to automatically and objectively deal with the most common exceptions like tied movers, manning priority billets, 'sailor priority' programs, etc.

Gapped P2 &3 and Non-priority Billets. In the process, unmatched Priority 2, 3 and non-priority billets are recycled indefinitely. Billets that are difficult to match in one cycle are likely to be difficult to match later as well. These billets may remain gapped for a prolonged period of time. EPMAC must examine these billets and propose ways to

make them more attractive to sailors.

Manual Matching. In order to ensure that all sailors are matched, manual methods have to be used to match sailors as a last resort. This introduces some level of human subjectivity into the process at this level, which the redesign had hoped to avoid. However, these numbers are expected to be small. To alleviate the need for manual matching, the relatively fixed PRD of sailors can be relaxed and moved to a later date. Sailors who fail to be automatically matched may opt to remain in their current billet until they are automatically assigned a billet, in effect delaying their PRD. It must be noted that this might in turn bounce off a sailor that is slated to take that billet, causing a chain effect. Therefore, this option is more suitable for billets to which no other upcoming sailors have yet been assigned to.

Gaming. Sailors and commands who know that they have three cycles to be automatically matched may game the process. Sailors may try their luck by listing their ideal but unrealistic choices in the first cycle, becoming realistic in later cycles. This will add to backlog in the process, a delay of assignment orders being written, and a delay in sailors and commands being informed. The requirement to list a certain number of P1 and P2 billets in their preference list, and constraining sailors to list only billets in which they rank well (say the top 50%) will alleviate this problem. Likewise, commands, through the placement officers, may state requirements that are too stringent, in the hope that they get only the best sailors. However, this may backfire and result in most sailors being scored and ranked low for that billet, lowering the chances of matching that billet. This too will add to the backlog and lower the proportion of matches completed by the two-sided matching runs. This problem may be alleviated by the weighted scoring method described in the process. The weighted scoring method forces commands to make tradeoffs among their desired sailor attributes. In effect, if a command states that all the attributes are important, the scoring method will assume that all the attributes are equal in importance – the same effect as stating that they are all only moderately important.

D. CHAPTER SUMMARY

A Baseline Approach. A baseline methodology was adopted in the process redesign making important changes to the process while retaining some of the current institutions and activities. It targets some key elements of the process for redesign, while leveraging on the strengths of the current process and available technology. This pragmatic approach will make implementation easier.

The Redesigned Process and the DSS in Brief. The redesigned distribution process consists of five main steps. A new DSS called NERISSA (Navy Enlisted Resource Integrated System for Smart Assignments) is specified to complement the process. The new distribution process and the NERISSA modules that accompany each step, is summarized in Figure 9 on the next page:

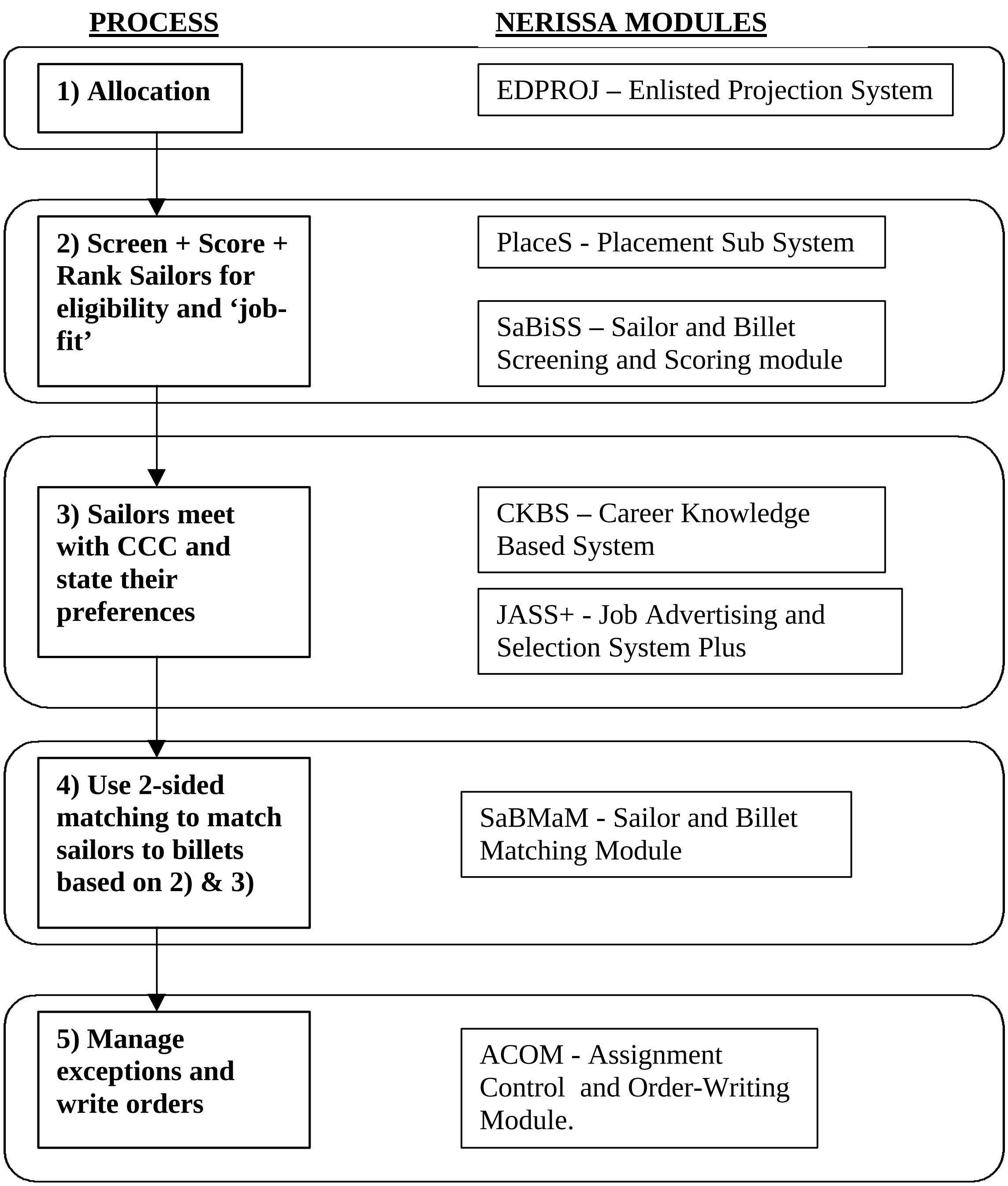

Figure 9 – Summary of the Redesigned Process

The first step is the allocation sub process, which remains largely unchanged from the current allocation process.

Step two is the screening and scoring stage. Sailors are screened for eligibility for billets based on their characteristics. These characteristics are matched to the job requirements and sailors who meet the job requirements are short-listed. The short-listed sailors are then scored based on how well they fit the commands' requirements. This chapter describes the screening and scoring attributes and metrics used. The Sailor and Billet Screening and Scoring module (SaBiSS) of NERISSA automatically performs this operation. The ranked sailors are then forwarded to JASS+ where sailors can view their standings among all the billets for which they are eligible, and to the Sailor and Billet Matching Module (SaBMaM) for matching sailors to billets later.

In step three, sailors meet with their command career counselors (CCCs) to receive career guidance and then 'apply' to billets for which they are eligible, with each sailor stating their billet preferences in ranked order. CCCs use the Career Knowledge Based System module of NERISSA to produce a career advisory for sailors that takes into account their preferences, career paths, billet availability, and other manning and personnel polices. Sailors use JASS+ to view eligible billets and their details before entering their preferences. Their preferences are then forwarded by JASS+ to SaBMaM for the matching to be done.

In step four, the process uses a command biased two-sided matching algorithm to assign sailors to billets based on the sailors' list of preferences and the commands' list of preferences. This is automatically done by the SaBMaM module of NERISSA. The matched pairs of sailor and billets are sent to the Assignment Control and Order-Writing Module for detailers and EPMAC to review the matches before orders are eventually written. Unmatched sailors and billets are recycled to the next distribution cycle to be matched again.

In step five, exceptions are managed, and matched sailors and billets are audited for fit and adherence to policies, before the orders are written. Exceptions include sailors and Priority 1 billets that have gone repeatedly unmatched for the previous 3 matching cycles. These sailors and billets are matched using an optimization algorithm that seeks to maximize sailor to billet fit based on sailor attributes and command needs. Sailors who are still not matched after this will be manually matched. EPMAC uses NERISSA's ACOM module to audit and finalize all assignments made before orders are written and electronically sent to sailors, commands, detailers and placement officers.

Dealing with Exceptions. The process is also robust enough to deal with tied movers, sailors who do not state their preferences, sailor priority programs, and units that require their complement to be on board 9 month in advance before deployments. In this process, sailors and commands are informed at least 5 months before PCS of their assignments.

Benefits. The benefits of the redesigned process over the current process, includes streamlined information flows and radically improved timeliness and accuracy of the capture, transfer, processing and delivery of important information to the users. Also, sailors' expectations and needs are managed and met through an objective and fair process. As the redesigned process promotes stable matches, sailors and commands are less likely to seek alternative assignments. Also, by automating many of the tedious tasks with NERISSA, the efficiency and accuracy of the process is drastically improved by reducing the labor and time required for the matching operations. However, despite the extensive use of technology, the all important 'human touch' is still preserved in the process though the CCCs' interaction with the sailors.

Shortcomings. The redesigned process has a few shortcomings that arise mainly from the need to cater to the diversity of situations faced in personnel operations. As some of the matches have to be forcibly (by optimization) or manually matched, a small number of matches may not be stable. Also, unmatched Priority 2, 3 and non-priority billets are recycled indefinitely and may be gapped for a prolonged period of time.

Finally, sailors and commands may also game the process by trying their luck in the first few cycles. However, these shortcomings are small tradeoffs in the redesigned process that is robust enough to handle the main exceptions to the norm.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis examines the prospect of improving the current distribution process with an innovative process redesign integrating enabling technologies. It demonstrates that despite the many constraints inherent in the Navy's situation, it is possible to design a process that makes quantum improvements to the distribution process, through the integrative application of innovative process design and technology. Although there are several limitations of the proposed process, it largely satisfies the critical success factors spelt out at the beginning of the redesign process. The process is also robust enough to adapt to many different situations that may occur in the distribution process. The process and its supporting DSS outlined in this thesis serves as a platform where more detailed research can be done to further develop the process and its components.

In particular, this thesis has detailed the following findings and proposals:

<u>Shortcomings of Current Distribution Process</u>. The shortcomings of the current distribution process stem from the fact that it is largely manual. The end result of these shortcomings is that commands do not get their required number and quality of sailors. Non-optimal assignments are common and commands often do not get the best sailor for the job. Detailers continually struggle to manage the Navy's requirements and the sailors' wishes, and mistakes are easily made. Being manual, the process is subject to human error. Another problem with the distribution process is that the sailors' needs, wants, and desires frequently take a back seat to the Navy's needs. Despite the changes in the process and the improvements introduced by JASS, sailors and commands continue to perceive the process as being subjective. Sailors believe that not all jobs are displayed on JASS and that the detailers 'hold' the best jobs for their friends and acquaintances. The entire distribution process is extremely labor intensive with long cycle times and multiple feedback loops to collect and reaffirm information. This is caused in part by redundancies in the process that hinders the efficiency of the process. For example, CCCs, detailers and

EPMAC all screen sailors for eligibility at multiple stages in the current process when it need only be done once. Finally, the current process promotes gaming activities by the sailor. The sailors know that the process runs in two-week cycles. If the sailors do not see jobs that they want on JASS, they have the option to do nothing and wait for the next cycle with the hope that the next batch of available jobs will contain jobs they want.

Enabling Technologies. The enabling technologies discussed in this paper include matching algorithms and decision support system technologies. Two-sided matching algorithms can match sailors to billets that take into account their preferences. They can meet sailors' preferences without unduly sacrificing commands' needs, subject to some adjustments to the process. Optimization and scoring algorithms and metrics allow sailors to be screened, scored and ranked according to a set of attributes. It can also be used to force match sailors to billets while optimizing the sailor-to-billet fit. Intelligent agents can deal with large amounts of data from distributed sources and autonomously represent commands' and sailors' needs to the process. A knowledge based system can assist CCCs in counseling sailors with the latest information available. It can also propose a course of action for the sailors through a personalized career advisory generated by intelligent features in the system. Finally, all these systems can, and have to be, integrated as a dynamic whole and to function seamlessly. The distribution DSSs can reside on the NMCI infrastructure, thus reducing set up time and costs. This also allows the web-based system to reach all the Navy's distributed intranet users in far flung geographic locations. Although the technology has the ability to substitute human labor, the 'human touch' is maintained in the redesigned process. Sailors and commands must feel that they are being looked after by thinking and feeling personnel who they can talk to and trust. Technology is used to enhance the decision making abilities of detailers and CCCs and not replace them.

Constraints Unique to the Navy. There are unique constraints and objectives in Navy personnel policy that significantly impact the design process and modifications will have to be made to the technologies and process design to account for these constraints. The constraints that would have to be considered in the redesign process were examined

using the four management frames– structural, human resource, political/power, and symbolic/cultural. Structural constraints include prioritizing billets given the shortage of sailors to fill all billets, and the issue of tied movers (assigning married couples in the Navy to the same locations). Another constraint is posed by sailors who have family members with special needs, falling under the Exceptional Family Member Program (EFMP), and can only be assigned to commands with services that support the program. Relatively fixed PRD and the need to assign all sailors to a billet or a training slot also pose process constraints. Human Resource issues that need to be considered include the need to maintain human-to-human interaction in the process, the need to streamline the number of parties sailors contact about career and assignment issues, and the need to manage the perceptions of equity among sailors. Political and Power issues include the detailers' ability to decide the sailors' assignments. If an automated matching system were implemented, the detailers' power to decide assignments needs to be curtailed to those instances that require manual matching. The power to audit the process needs to fall to a third party – EPMAC to ensure parity, fairness and proper functioning of the process within policy boundaries. The 'expert power' of CCCs also needs to be reinforced and not diminished by implementing technology. A knowledge based career counseling system can reinforce the CCC's role to educate and persuade sailors on career choices. Finally, the culture of the military where sailors are expected to put 'duty before self' must be maintained despite the ability for the process to give sailors more say in their assignments. The dictum of 'Fairness' in managing sailor careers must strike a sound balance between the Navy's needs and the sailors' welfare. Only then will sailors embrace the virtue of 'duty before self.' The redesigned process must be objective, fair and promote this virtue rather than erode it.

Proposed Redesign. This thesis proposes an integrated, innovative, robust and practical Enlisted Personnel Distribution process that will achieve quantum improvements over the current manual process of assigning sailors to billets. The proposed process is much more efficient (requiring less resources, fewer errors) and effective (better sailor-to-billet matches, and higher command and sailor satisfaction). It also details the key operational specifications of a proposed accompanying Decision

Support System (called NERISSA – Navy Enlisted Resource Integrated System for Smart Assignments) that leverages on tested technology to make the improvements to the process. Both the process and DSS are integrated in their synergistic designs to achieve optimal gains.

Past studies show that significant positive results can be reaped if the two-sided matching algorithm is used in the Navy to match sailors to billets. Other research have also detailed the possible uses of optimization technology, smart agent technology, employee-to-job matching algorithms, and incentive driven assignments to improve on employee-job assignments in large hierarchical internal labor markets, like those found in the military. It is also noted that there are unique structural, behavioral, political, and cultural constraints within the US Navy that can pose challenges to the direct application of these technologies to improve the process. To improve the current process, both the available technologies and constraints are reexamined holistically. This study used a baseline methodology of Process Redesign to integrate these constraints and available technology into an innovate redesign of the Distribution Process. Innovative modifications were made to the algorithms and technology to cater to the Navy's unique personnel policy constraints.

The redesigned distribution process consists of five main steps:

The first step is the allocation sub process, which remains largely unchanged from the current process.

Step two is the screening, scoring and ranking stage. Sailors are screened for billets for which they are eligible and they are then scored by each of these billets based on how well they fit the job requirements. They are then rank ordered based on their scores, thus producing lists of billets' preferences for eligible sailors. The Sailor and Billet Screening and Scoring Module (SaBiSS) in NERRISA performs this operation automatically at the start of each month-long matching cycle. Placement Officers can enter their commands' preferences of sailor attributes by setting their weights through the

Placement Sub-System (PlaceS) module of NERISSA. SaBiSS then uses these command ‘personalized’ metrics and weights for each billet for the screening and scoring process.

In step three, sailors meet with their Command Career Counselors (CCCs) to receive career guidance. CCCs can use the Career Knowledge Based System (CKBS) module of NERISSA to produce a personalized career advisory for every sailor that incorporates the latest personnel and career management policies and individual sailor attributes. Sailors then apply to billets for which they are eligible, with sailors stating their billet preferences in ranked order. Sailors do this through the JASS+ module of NERISSA. In JASS+ sailors can view billet information and description, list their preferences and track their progress in the matching cycle.

Step four then uses two-sided matching algorithms to assign sailors to billets based on the sailors’ list of preferences and the commands’ list of preferences from steps two and three. The Sailor and Billet Matching Module (SaBMaM) of NERISSA does this automatically by using information fed from SaBiSS and JASS+.

In step five, exceptions are managed, and matched sailors and billets are audited for fit and adherence to policies, before the orders are written. Summary reports, audits, approval, and order writing is done through the Assignment Control and Order-Writing Module (ACOM) of NERISSA.

<u>Benefits of Redesigned Process</u>. The benefits of the redesigned process over the current process include, streamlined information flows and radically improved timeliness and accuracy of the capture, transfer, processing and delivery of important information to the users. Also, sailors expectations and needs are managed and met through an objective and fair process. As the redesigned process promotes stable matches, sailors and commands are less likely to seek alternative assignments. Also, by automating many of the tedious tasks with NERISSA, the efficiency and accuracy of the process is drastically improved by reducing the labor and time required for the matching operations. However,

despite the extensive use of technology, the all important ‘human touch’ is still preserved in the process though the CCCs’ interaction with the sailors.

Shortcomings of Redesigned Process. The redesigned process has a few shortcomings that arise mainly from the need to cater to the diversity of situations faced in personnel operations. As some of the matches have to be forcibly (by optimization) or manually matched, a small number of matches may not be stable. Also, unmatched Priority 2, 3 and non-priority billets are recycled indefinitely and may be gapped for a prolonged period of time. Finally, sailors and commands may also game the process by trying their luck in the first few cycles. However, these shortcomings are small tradeoffs in the redesigned process that is robust enough to handle the main exceptions to the norm.

B. RECOMMENDATIONS

This paper recommends the following:

Firstly, this thesis should serve as a platform for further research leading to trails to be conducted by NPRST in Aug 2002 to automatically match E-9s to billets using the process and technology highlighted in the paper. By integrating the various studies done so far into a pragmatic process, this thesis hopes to propel the research done so far to the trail and implementation stage of the project mandated by NPRST. The concepts and main considerations of this research should constitute key elements of the trail and eventual design.

It is recommended that experiments be conducted to verify the tolerance of the redesigned process to the constraints of the Navy. Studies should also be done to detail the variables (preferences, attributes, cycle length, etc.) in the process and to verify that the variables proposed in this study are optimal for the process to work well. The studies that should be conducted are detailed in the next section.

C. FURTHER STUDIES

It is recommended that the proposed process and its supporting DSS be used as a platform from which more detailed studies can be launched. The main areas of studies include: 1) empirical research into the variables and verifying the potential performance of the process, 2) examining Navy personnel policies that impact and in turn are affected by the proposed process, and 3) further research required to produce prototypes of NERISSA.

Empirical Research. The proposed process and accompanying technology require several key details before they can be operationalized. These details can be examined by empirical means – either with simulations or experiments, or both. In particular, the following empirical questions and research areas can form the basis for subsequent studies:

- What key variables' values will produce the best results for the matches? Key variables include the matching cycle length, the number of sailor and billet attributes and their weights, the ideal number of cycles before being forced matched, the number of billets sailors must list in their preferences, and the number of priority billets that must be included in preference lists. All these factors impact the quality (i.e., the stability of matches, and degree to which sailors' and commands' preferences are met) and proportion of automatic matches. Simulation modeling using 'real life' data can simulate the redesigned process and is useful in determining the impact on the matches if parts of the process and characteristics of the key variables are varied. The process and its variables' metrics can then be fine-tuned and verified to produce the desired results

- What impact do tied movers and the other exceptions have on the stability of the matches? Is there a significant impact on the overall stability of the

matches?

- What is the percentage of automatic matches? How can the process be improved to increase this percentage?

Examining Personnel Policies. Some of the proposals in this thesis require the Navy leadership to examine some of its personnel policies. Some of these issues include the following:

- What incentives should be given to sailors to encourage them to apply for undesirable billets? Should there be monetary incentives, giving sailors in these billets priority in their next assignment, or both?

- The proposed process produces data on the 'desirability' of sailors and jobs through sailors' and billets' scoring and ranking of one another. How can the Navy use this data to better retain highly ranked sailors (as measured by a spectrum of objective attributes) as these sailors are in high demand? What should the Navy do with 'undesirable' sailors who are consistently ranked low by the relevant billets – reflecting the organization's low demand for them. How can the Navy improve the conditions of undesirable billets?

- Should manning targets spelt out in the NMP be met over a longer period compared to the current practice to balance the actual versus targeted manning at every cycle? How long should this period be and what method should be used to achieve the manning targets?

Developing a Prototype of NERISSA. In conjunction with studies to determine how the proposed process can be further improved, studies should be conducted to examine how prototypes of NERISSA modules should be concurrently developed. This will allow NERISSA's features to be trailed together with process fine-tuning and verification. Among these studies, two area should be considered further:

- Given NERISSA's modular nature, prototypes of some of the modules can be constructed first and tested. In particular, the scoring and screening (SaBiSS) and matching modules (SaBMaM) can be prototyped and put through their paces with simulated or live data (using real sailors' and commands' preferences). Subsequently, the other modules of NERISSA can be prototyped and integrated.

- This thesis proposed a intelligent Career Knowledge Based System (CKBS) that has among its features, the ability to produce individualized career advisories for sailors given their preferences, billet availability, career path and other personnel policies. Further research is required to determine what models need to be used in the CKBS, which relevant policies must be included, and what specific technologies need to be used to produce the advisory. Also, as the CKBS will have a library of references on personnel and career policies, a study will have to be done to determine exactly what information should go into that library. A process will also have to be developed so that the information will be kept current.

<u>Application of Technology and Process to Other Services and Militaries</u>. Other studies can be conducted to see how the technologies, methodologies and processes highlighted in this paper can be applicable to other services (Army and Airforce) and militaries who face similar challenges, but have different constraints, in matching their personnel to jobs. Lessons learned from these studies may be applicable to the US Navy's situation.

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APPENDIX A

2-SIDED MATCHING ALGORITHM - A CLASSICAL ALGORITHM FOR STABLE MARRIAGE (Ng and Soh, 2001)

2-sided matching algorithm can be employed to achieve stable marriage matching of sample size n. A stable matching is a complete matching of men and women such that no man and woman who are not partners both prefer each other to their actual partners under the matching. (Irving, Leather & Gusfield, 1987)

In an instance of the stable marriage problem, each n men and n women lists the members of the opposite sex in order of preference. This classical algorithm normally yields what is called the male optimal solution, with the property that every man has the best partner that he can have in any stable marriage. If applied with the roles of men and women interchanged, the algorithm will yield the female optimal solution, which similarly favors the women. The achievement of best possible partners by the members of one sex results in the members of the opposite sex having their worst possible partners.

MATCHING ALGOTHM MEN BIAS

MEN	PREFERENCE							
1	3	1	5	7	4	2	8	6
2	$\boxed{6}$	1	3	4	8	7	5	2
3	7	4	3	6	5	1	2	8
4	5	3	8	2	6	1	4	7
5	4	1	2	8	7	3	6	5
6	6	2	5	7	8	4	3	1
7	$\boxed{7}$	8	1	6	2	3	4	5
8	2	6	7	1	8	3	4	5

WOMEN	PREFERENCE							
1	4	3	8	1	2	5	7	6
2	3	7	5	8	6	4	1	2
3	7	5	8	3	6	2	1	4
4	6	4	2	7	3	1	5	8
5	8	7	1	5	6	4	3	2
6	5	4	7	6	$\boxed{2}$	8	3	1
7	1	4	5	6	2	8	3	$\boxed{7}$
8	2	5	4	3	7	8	1	6

MEN	PREFERENCE							
1	3	1	5	7	4	2	8	6
2	6	$\boxed{1}$	3	4	8	7	5	2
3	7	4	3	6	5	1	2	8
4	5	3	8	2	6	1	4	7
5	4	1	2	8	7	3	6	5
6	6	2	5	7	8	4	3	1
7	7	$\boxed{8}$	1	6	2	3	4	5
8	2	6	7	1	8	3	4	5

WOMEN	PREFERENCE							
1	4	3	8	1	$\boxed{2}$	5	7	6
2	3	7	5	8	6	4	1	2
3	7	5	8	3	6	2	1	4
4	6	4	2	7	3	1	5	8
5	8	7	1	5	6	4	3	2
6	5	4	7	6	2	8	3	1
7	1	4	5	6	2	8	3	7
8	2	5	4	3	$\boxed{7}$	8	1	6

MEN	PREFERENCE							
1	$\boxed{3}$	1	5	7	4	2	8	6
2	6	$\boxed{1}$	3	4	8	7	5	2
3	$\boxed{7}$	4	3	6	5	1	2	8
4	$\boxed{5}$	3	8	2	6	1	4	7
5	$\boxed{4}$	1	2	8	7	3	6	5
6	$\boxed{6}$	2	5	7	8	4	3	1
7	7	$\boxed{8}$	1	6	2	3	4	5
8	$\boxed{2}$	6	7	1	8	3	4	5

WOMEN	PREFERENCE							
1	4	3	8	1	$\boxed{2}$	5	7	6
2	3	7	5	$\boxed{8}$	6	4	1	2
3	7	5	8	3	6	2	$\boxed{1}$	4
4	6	4	2	7	3	1	$\boxed{5}$	8
5	8	7	1	5	6	$\boxed{4}$	3	2
6	5	4	7	$\boxed{6}$	2	8	3	1
7	1	4	5	6	2	8	$\boxed{3}$	7
8	2	5	4	3	$\boxed{7}$	8	1	6

MEN	PREFERENCE							
1	$\boxed{3}$	1	5	7	4			
2	$\boxed{1}$	3	4	8	7			
3	$\boxed{7}$	4	3	1	2	8		
4	$\boxed{5}$	8	6	1	4	7		
5	$\boxed{4}$	2	8	7	3	6	5	
6	$\boxed{6}$	5	7	4	3			
7	$\boxed{8}$	6	2	3	4	5		
8	$\boxed{2}$	7	1	3	5			

WOMEN	PREFERENCE							
1	4	3	8	1	$\boxed{2}$			
2	3	7	5	$\boxed{8}$				
3	7	5	8	3	6	2	$\boxed{1}$	
4	6	4	2	7	3	1	$\boxed{5}$	
5	8	7	1	5	6	$\boxed{4}$		
6	5	4	7	$\boxed{6}$				
7	1	4	5	6	2	8	$\boxed{3}$	
8	2	5	4	3	$\boxed{7}$			

Figure A1: Male And Female Preference Lists

The classical algorithm for a solution to a stable marriage instance is based on a sequence of “proposals” from the men to the women. Each man proposes, in order, to the women on his preference list, pausing when a woman agrees to consider his proposal, but

continuing if a proposal is either immediately or subsequently rejected. When a woman receives a proposal, she rejects it if she already holds a better proposal, but otherwise agrees to hold it for consideration, simultaneously rejecting any poorer proposal that she may currently hold. (A "better" proposal means a proposal from some man higher in the woman's preference list.)

Hence after first round, it can seen from the example in Figure A1, men [2] and [7] would have received the rejection from the woman first on their preference list. The match [2,6] and [7,7] are considered unstable matches and shaded gray. Men [2] and [7] will now propose to the women second on their preference list, highlighted in white. 3 scenarios can happen:

- **Women accept proposal, rejecting proposal they held earlier from other men**. The other man would have to "move on" and propose to the woman of their second choice. The process of proposal is repeated again for the rejected men.
- **Women rejecting the proposal by men [2] & [7]**. The unstable matches would be shaded gray and the men moved on to propose to the women next on their list.
- **Women accepting the proposal, with no prior proposal from other men**. The process represents a stable match and nobody gets rejected.

The process is repeated until all matches are stable. In this example, the stable match scenario occurs when men [2] & [7] proposed to their second choice women.

It can thus be shown that, the sequence of proposals will result in every woman holding a unique proposal, and that the proposals held constitute a stable matching. (A similar outcome results if the roles of males and females are reversed, in which case the resulting stable matching may or may not be the same as that obtained from the male proposal sequence). Two fundamental implications of this initial proposal sequence are

- If a man, *m*, proposes to woman, *w*, then there is no stable matching in which *m* has a better partner than *w*;
- If *w* receives a proposal from *m*, then there is no stable matching in which *w* has a worse partner than *m*.

These observations suggest that we should explicitly remove m from *w*'s list, and *w* from *m*'s, if *w* receives a proposal from someone she likes better than *m*. These are shaded in gray in the example in Fig.A1 and the resulting list is called the shortlist (male-oriented) for the given problem instance, with the following properties:

- If *w* does not appear on *m*'s shortlist, then there is no stable matching in which *m* and *w* are partners.
- *w* appears on *m*'s shortlist if and only if *m* appears on *w*'s, and is first on *m*'s shortlist if and only if *m* is last on *w*'s.
- If every man is paired with the first woman on his shortlist, then the resulting match is stable; it is called the male optimal solution, for no man can have a better partner than he does in this matching, and indeed no woman can have a worse one.
- If the roles of males and females are interchanged, and if every woman is paired with the first man on her (female-oriented) shortlist, then the resulting matching is stable; this would be a female optimal solution, for no woman can have a better partner than she does in this matching, and indeed no man can have a worse one.

APPENDIX B

OTHER MATCHING METHODS USING OPTIMIZATION ALGORITHMS - BENEFITS AND SHORTCOMINGS

Introduction

Apart from using the two-sided matching algorithm to match sailors to billets based on their ranked preferences, optimization technologies may also be used to match sailors to billets. Regardless of the optimization technology used (GAMS, genetic optimization etc.), optimization seeks to maximize the utility of either, both, or the adjusted weighted average of sailors' and commands' utility through matching combinations of sailors and billets. In this case, sailors' and commands' utilities are manifested in their respective scores and ranked preferences of one another. This appendix discusses in brief the different optimization options available. It also presents their benefits and shortcomings.

Option 1 : Optimize Commands' Utility only.

In this option, the optimization algorithm finds the combination of sailor-billet pairs that maximizes the sum of the commands' total satisfaction by maximizing the sum of the sailor's 'Should Have' scores. Algebraically:

Maximize : Sum of Total Sailor Score = $\sum(S_{ij}^{T})$

Where : S_{ij}^{T} is the total sailor score of sailor i, derived from comparing sailors i's individual attributes and billet j's requirements.

Benefits. Command's utilities are maximized in this option. On the whole, commands get the best mix of sailors given their job requirements and policy constraints. Also, in the usual situation where there are fewer sailors than billets, all eligible sailors

will be matched to a billet.

Shortcomings. The main shortcoming of this option is that sailors' preferences are not considered. Therefore, matches will not be stable. Also, individual commands may not get their most favored sailor as the optimization will tradeoff scores of the matched pairs to get an overall highest sum of all the sailors' scores.

Option 2 : Optimize Command Utility While Considering Sailors' Preferences.

Option 2 is variant of option 1. Here, the optimization finds the combination of matched pairs that maximizes the sum of the total of commands utility (sailors' score) and the score derived from the sailors preference of the billet, $\sum S_{ij}^{TS}$. Algebraically,

Maximize : $\sum S_{ij}^{TS} = \sum(S_{ij}^{T} + S_{ij}^{P})$

Where : S_{ij}^{T} is the total sailor score of sailor i, derived from comparing sailor i's individual attributes and billet j's requirements.

S_{ij}^{P} is a 'preference' bonus score if sailor i's preference list includes billet j. That score will be zero if billet j is not on sailor i's preference list, and increases as the preference increases.

Benefits. This option maximizes the sum of the commands' utilities while considering sailors' preferences as a valued attribute. This option can be viewed from the perspective that commands value sailors that choose them. Also, if there are fewer sailors than billets, optimization can force match eligible sailors to a billet.

Shortcomings. Unlike the two-sided matching algorithm that will not match a sailor to a billet if the sailor does not list the billet as a preference, this option may match commands with sailors who do not prefer the billets. Therefore, such matches are not stable. However, in the process where sailors are educated to choose billets for which

they score well, this shortcoming is mitigated. Another shortcoming is that commands may not be assigned sailors that score well because sailors can make up for a low sailor attribute score (i.e. a low S_{ij}^{T}) if they rank that billet highly (a high S_{ij}^{P}).

Option 3 : Optimize The Sum Of Sailors And Command's Utilities

In this option, the optimization algorithm finds the sailor-billet pairs that maximize the sum of the commands' utility and sailors' utility by maximizing the sum of the sailors' 'Should Have' scores and billets' score when sailor's preferences are compared against billets' attributes. Algebraically,

Maximize : Summation of Total Score = $\sum S_{ij}^{TS} = \sum(S_{ij}^{T} + S_{ij}^{B})$

Where : S_{ij}^{T} is the total sailor score of sailor i, derived from comparing sailor i's individual attributes and billet j's requirements.

S_{ij}^{B} is the total billet score of billet j, derived from comparing billet's attributes and sailor i's preferences over each billet attribute.

Benefits. This option considers both commands' and sailors' preferences as a whole. Also, all eligible sailors can be assigned a billet if the number of sailors exceed the number of billets.

Shortcomings. To maximize the sum of the total score, there may be tradeoffs between sailors' and command's preferences if they are dichotomous. In some matches, a high total sailor score may see a correspondingly low billet score, or vice versa. In such cases, the optimization will trade off one component score for the other to achieve a maximum total score – increase S_{ij}^{T} but decrease S_{ij}^{B}, or vice versa. Given the complexity generated by the large number of match combinations, it becomes unpredictable which component will be sacrificed. It becomes unpredictable whether sailors' or commands' needs will be sacrificed. Sailors may still be matched to billets that they do not prefer or vice versa. Therefore, there may be a problem with unstable matches. This situation may

be mitigated by educating sailors and limiting them to only listing billets for which they score well.

Recommendations

The above optimization options do not produce stable matches as they do not satisfactorily consider sailors' preferences along with billets' requirements. All the options above may match sailors to billets even if the sailors do not include them in their preference list, if the sailors' score is sufficiently high to offset a zero billet score. Even if sailors preferences are considered as a component of the total score to be optimized, the process may produce unpredictable results that may trade off commands' needs for sailors' needs and vice versa.

Given these concerns, it is not recommended that optimization methods be used as a primary method to match sailors and billets. However, optimization can be used to force matches while optimizing one or both party's utilities. Thus, optimization may ensure that all the sailors left unmatched after a two-sided matching run, will be matched to a billet while ensuring the best combinations of sailor-billet pairs that maximize the overall sailor-billet fit.

APPENDIX C

ALTERNATIVE PROCESS TO DEAL WITH TIED MOVERS

In the context of this thesis, tied movers refer to Navy enlisted personnel who are married to another Navy enlisted sailor. The Navy's assignment policy is to co-locate these couples (assign to billets in the same general location, eg. San Diego, Norfolk etc.), as long as they do not opt out of this the policy. This appendix considers an alternative to the method proposed in Chapter IV of this thesis on how to modify the two-sided algorithms in the assignment process to account for these exceptions.

Alternative Process

Roth and Peranson (1999) in their design of the matching market for American physicians describe an alternative for dealing with tied movers. To recall, the two-side matching algorithm first sees each sailor proposing to a billet. Each sailor is then tentatively matched to a billet until another sailor proposes to that billet. If the billet prefers the latest sailor, the earlier sailor tentatively matched will be 'bounced off.' The 'bounced off' sailor then proposes to the next billet down his/her rank order preference list, and is tentatively matched to it. The process repeats itself until all sailors are no longer upstaged by any other sailor.

In the case of couples, preferences of billets are made in pairs (i.e. if sailor A states a billet in Hawaii as his first choice, his spouse must also state a billet in Hawaii as her first choice). Roth and Peranson design proposes that an applicant (sailor) who gets upstaged by another from his tentative assignment (because the billet prefers another sailor who proposes to it) will also see his partner losing her tentative assignment even if she is not upstaged by another applicant. This is because the proposals made by couples to positions (billets) are in tied-pairs. When one gets bounced off, the other gets bounced off too. Both members of the couple will then be tentatively matched to their next pair of

billet choices lower in their ranked ordered preference list, and the process repeats itself till *neither* couple is upstaged by another sailor.

Benefits

The outcome is a stable match for all the sailors and billets in the process if the couples' preferences are considered as inseparable pairs. It also avoids any chain reaction that might lower the overall stability of the matches if a sailor occupies a billet that prefers another sailor.

Shortcomings

This alternative penalizes the tied movers by 'bouncing' them lower down their preferences list. The pairs of billets must also *concurrently not* prefer any other sailor, or else *both* tied movers will get bumped off and their next pair of billets down their preference list considered. If one partner is upstaged by another sailor, the other partner will also have to 'vacate' the billet, even if he is not upstaged by another sailor. This increases the likelihood that tied movers will keep being bumped down their list of preferences, until both are considered as the most preferred by the billet pairs. The penalty that tied movers pay in this alternative may run contrary to the spirit of the Navy's tied mover policy, which is to promote family life. If such a penalty is imposed, the attractiveness of the policy will be eroded and the Navy may be seen as "giving with one hand, and taking back with the other."

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